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Abstract:

This deliverable describes the results of the demonstration activities of the eWALL project.

Keyword list:

Large Scale Evaluation; Clinical Protocol; Mild Cognitive Impairment (MCI); Chronic Obstructive Pulmonary Disease (COPD); Age Related Impairment (ARI); Acceptance of Technology; Descriptive Statistic; ICT; Tele-monitoring; Quality of life; User Experience; perceived quality of life

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2.3	November 30, 2016	Sofoklis Kyriazkaos	Final review and approval

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1 Executive Summary

The demonstration phase of the Large Scale Evaluation study was planned to assess the feasibility of a home intervention using the eWALL. The endpoints of the study included the user acceptance, adherence and potential clinical outcome after 4 weeks of system use at home. The aim of the deliverable was to evaluate methods and explore results to **gain an initial idea about the potential added value for clinical practice and possible working mechanisms.**

Given the development stage of the technology the epidemiological design most suitable to reach the aims of the deliverable was the **proof-of-principle study.** These small-scale studies are common in clinical studies, and are designed to detect a signal that the treatment or drug is active on a relevant mechanism, as well as preliminary evidence of efficacy in a clinically relevant endpoint. Translating this approach to the eWALL project, an experimental study was designed with the purpose of demonstrating the suitability of the produced platform for the use in patients with functional impairments due to aging or to the presence of chronic diseases. This proof-of-concept study was especially focused on gaining information about acceptance of the system, and more specifically the use and acceptance of its individual components. No significant modulations of the cognitive and physical status would be observed within the few weeks of installations.

The study population was represented by three main target populations (subjects affected by Chronic Obstructive Pulmonary Disease (COPD), by Mild Cognitive Impairment (MCI), by a group of elderly at risk of losing their physical, cognitive or psychological functions in short time, defined as Age related Impairment(ARI) group), and four evaluation sites in the Netherlands, Italy, Denmark and Austria. The evaluation is focused on three main study parameters. The primary study parameters are User Experience and Use of eWALL, and the secondary study parameter is the Potential Clinical Effect. The inclusion and exclusion criteria for each group investigated is reported in the Section 3.1.The four demonstration sites within the eWALL project had some level of freedom in arranging the procedures and installation of the eWALL platform during the demonstration trials. The details regarding the eWALL installation and organizational procedures of each center are reported in Section 3.2.

Different strategies of patients' recruitment were followed by different partners. Patients in the Netherlands were recruited at various physiotherapeutic centers (21 COPD patients), in Denmark at the Hjørring Sundheds Center, a municipal health clinic (2 COPD and 5 ARI), in Italy through the Day Hospital Unit of the IRCCS San Raffaele Pisana in Rome (15 MCI), in Austria through an existing dataset of users (5 ARI). A much larger group of subjects was evaluated as potential candidates to enter the study. After explaining in detail the study plan, all subjects were asked to sign the informed consent.

All participants of the demonstration study received information about the aim of the project, followed by a training session at the day of the eWALL installation in their home. The trainings session addressed the eWALL system and its available features by exploring the eWALL system functions. After completing the training session successfully, the participants were able to use the eWALL system on their own. Particular attention was paid to the MCI participants' training

procedure as subjects with mild cognitive impairments may suffer from difficulties to remember how to use the platform. To ensure a proper participation to the project, clinical partners provided continuous support for MCI participants and their caregivers. A specific support service was activated on request using the helpdesk system, whenever the user or his/her caregiver deemed it necessary. Moreover, manuals and clear instructions were provided to participants and their caregivers.

The level of user experience and the technology acceptance, were measured by a questionnaire based on the ***Technology Acceptance Model*.** The TAM+ questionnaire consisted of 34 items which can be divided into 7 domains: enjoyment, aesthetics, control, trust in technology, perceived usefulness, ease of use and intention to use. The original TAM questionnaire dates from the 1980s and has been used numerous times to assess and explain the acceptance of new technology. As a result, the core factors that make up TAM are accompanied by summated rating scales that have been validated in many contexts.

An additional tool was used in Austria. The ***User Experience Questionnaire* (UEQ)** was used to analyze eWALL's attractiveness, perspicuity, efficiency, dependability, stimulation and novelty. Attractiveness is defined as pure valence dimension. Perspicuity, Efficiency and Dependability are pragmatic quality aspects which are goal-directed, while Stimulation and Novelty are hedonic quality aspects that are not goal-directed. The 26 items have the form of a semantic differential, i.e. each item is represented by two terms with opposite meanings. Users have to rate each item between -3 and +3. To compare the measured user experience of the prototype with results of other products, the UEQ offers a benchmark to classify a product into 5 categories of the 6 scales: excellent, good, above average, below average and bad.

One of the most important tools was the *open interview* that was conducted at all evaluation sites, which consisted of 20 questions (with open answers) about technical issues, personal activity, sleep, health monitoring, domotics, self-management and the general experiences with eWALL. During the interviews, questions were asked that can be directly related to eWALL (functionalities), as well as more general questions, focusing on getting a picture about the participant's demographics and medical situation. ***Question Analysis*** (an approach focused on participants' responses to questions, related to specific screens or functionalities of eWALL) was applied for questions about technology, and ***Sensitizing Concept Analysis*** (an approach focused on concepts that are not interface-specific, such as trust in the system or the intention to use it) for the remaining questions.

The other critical objective of the eWALL evaluation study was to assess the ***Use of eWALL*** and its individual applications. In order to assess this, an interaction logging service was developed that keeps track of user's interactions with the user interface. The analysis of this data consists of filtering raw log data, annotating log events, and analyzing data.

The interaction log database was retrieved for all eWALL users participating in the studies. These raw log tables contain a number of oddities and 'false' events that need to be removed. The filtering of instances (i.e. rows in the excel file) concern events that do not regard a true interaction initiated by the user. After the filtering is completed, all remaining log events have been checked and annotated as belonging to the correct application. As far as the analysis of data is concerned,

interaction logs focused specifically on answering the following four questions: *How many times per day does the user interact with eWALL?; How many times in total did each user interact with each application?; Which applications are used every day, which applications are used sporadically?; At what time of the day is it more likely that the user interacts with eWALL?*

The last purpose of the demonstrator was to evaluate the potential clinical effect of the eWALL platform. This aim was addressed using several measurement instruments, some of which used in all the evaluation sites, such as the **Short Form (36) Health Survey (SF-36)** and the **Instrumental Activities of Daily Living (iADL)**, others specifically defined for the various different target populations, such as the **Clinical COPD Questionnaire (CCQ)** for COPD patients and **the Mini-Mental State Examination (MMSE)** for the MCI target group. Measurement of clinical endpoints differed in the four centers, according to the tool used and the moment of the measurement, i.e., Pre-measurement, the day of the eWALL installation, Mid-term evaluation moment (half-way during the trial period), Post-measurement, final day and pickup of eWALL, and Follow-up measurement, 6 weeks after Post-measurement.

A total of 48 subjects were prospectively enrolled between April and October 2016 in the four national recruitment centers and participated to the proof of concept study of the eWALL platform, as planned by the final phase of the project. Participants were stratified in three groups: 1) 15 MCI subjects, all recruited in Italy. The mean MMSE value was 23,74 and their intervention time slot lasted on average 29,6 days. 2) 23 COPD patients were enrolled in two countries, 21subjects in The Netherlands and 2 in Denmark. The GOLD score was available only for 12 patients, ranging from 2 to 4. The intervention time slot lasted on average 22,83 days, and 3) 10 ARI subjects, 5 from Denmark and 5 from Austria. Subjects were on average 66,4 years old, and the intervention time slot lasted on average 20,10 days.

The User Experience was assessed by different tools providing complementary results. **The TAM questionnaire provided globally positive results** from the three different groups of subjects. Results from MCI subjects, ARI subjects, and COPD patients are clearly shifted toward the positive side. Regarding MCI subjects five items out of 8 showed a mean score of 5 or more (the highest was 6.1 concerning a positive attitude towards the system, including the willingness to use it or recommend it to others). **The pattern of response from the group of COPD patients was slightly different from the group of MCI but substantially positive**, with scores of single items ranging from 4.4 to 5.6. In this case the perceived usefulness of the system was the item with the lowest score (4.4) showing they do not consider the system complex and uneasy to use.

Overall the feeling of ARI subjects can be classified as positive. They appreciated some features, while manifested their quite indifference with others, including the thrust in technology and the intention to use this kind of technology.

The ***open interview*** were administered at the beginning of the study with the purpose of providing a detailed characterization of study patients pre-study, and during/after the study to get the general feeling about the effect (or the potential effect) of eWALL on daily life, cognitive training, sleep quality, health monitoring, including their expectations about the system of their ability to independently interact with eWALL. An extensive description of all these items is reported after

stratification by disease group and national center. The most common complaint was about technical difficulties, which frustrated them in the use of some application, including the Fitbit. A common feeling of expectation was demonstrated by the interest expressed for health monitoring, organization of daily activities, and sleep control. Cognitive training generated expectation in the group of MCI, which was also the group more positive about eWALL, with a positive evaluation by 14 out of 15 participants.

The second part of the result session considered the use of eWALL, which was extensively monitored through an interaction logging service that logged each interaction of the user with the platform. The analysis of data focused on the four research questions, reported above. A general recommendation came from the evaluation of the logging functionality measuring, i.e., re-design the interaction log service to provide automatic, real-time insights into actual use of the platform and its individual applications. The summary about the question on the eWALL Interactions per day, showed as after an initial week of intensive eWALL use (likely caused by the novelty effect), users perform on average over 30 interactions with the eWALL on a daily basis. The list of most used applications showed as the most popular eWALL apps are the Sleep application and Activity application, followed by the Health- and Cognitive Games applications. Stratification by group shows as COPD users favor the Activity, Sleep and Health applications above all other eWALL functionalities, MCI users likes more the Cognitive Exercise, Activity, and Sleep applications, while ARI users favor the Sleep, Health and Activity applications, however, this group appreciated also secondary applications such as Domotics, Cognitive Exercise, Calendar and Video Exercise. The question about which applications are used every day, and which ones are used sporadically showed as My Activity Application (73.7% daily use), sleep Application (62.6% daily use), and Health Application (61.7% daily use), are the most popular and frequently used applications. The eWALL is a part of everyday life and is used throughout the waking hours of the day in a stable pattern (on average for all eWALL users).

Results concerning the potential clinical effects of the eWALL come from validated tools such as the SF-36 and the IADL questionnaires. As expected mean scores of these questionnaires comparing subjects at the beginning of the study and at the end did not revealed any difference, neither statistically nor showing trends in one direction. In the case of COPD patients also some physical capacity related scored were evaluated pre- and post-evaluation. The difference shown by the **TUG** and the **6MWT** for COPD patients, and **MMSE** and **NPS batteries** for MCI subjects, measured before and after the study did not show any statistical or substantial difference.

Overall the large scale evaluation study produced some sound evidence about the feasibility of a home intervention using the eWALL and the added value for clinical practice, which verifies our initial assumptions and strengthens our post-project activities.

2 Introduction

This document presents activities and findings of the eWALL project demonstration phase scheduled in a form of large scale study as approved by the local Ethics Committees. The first part of this deliverable describes the operative procedures and activities for the preparation phase of the demonstration. The eWALL was then evaluated as a standalone service designing a protocol for large evaluation that would focus on three main target groups, namely: subjects with Mild Cognitive Impairment – MCI; Patients with Chronic Obstructive Pulmonary Disease – COPD; Elderly people with Age Related Impairment – ARI. The main purpose of the Large Scale Evaluation was the feasibility of home intervention using the eWALL, encompassing assessment of user acceptance, adherence and potential clinical outcome after 4 weeks of system use at home.

During the course of the project, an experimental study was designed with the purpose of demonstrating the suitability of the produced platform for the use in elderly patients with age related functional impairments (focus on age related conditions). When considering the evaluation framework (DeChant et al., 1996; D8.1), it became evident that in the eWALL project the objective of the study would be the feasibility and usability of the eWALL technology, and nevertheless, the working mechanisms and potential effects. Given the timeframe, the limited resources and the development stage of the technology, it was agreed it was not feasible and relatively useless to try to carry out a definitive clinical trials. The evaluation study was designed to demonstrate the proof of concept, gaining an initial idea about the potential added value for clinical practice and possible working mechanisms.

This evaluation was performed using the eHealth service administered by eWALL as a stand-alone service. This proof of concept study was focused on user experience, acceptance, use and potential clinical effect. Thus, research questions were especially focused on gaining information about acceptance of the system. It is worth to highlight that it was quite unlikely that significant modulations of the cognitive and physical status would be observed within the few weeks of installations.

The aim of the deliverable is to describe methods and explore results to gain an initial idea about the potential added value for clinical practice and possible working mechanisms. The understanding of final results will be of fundamental importance and a strategic value for further exploitation of the eWALL system.

This deliverable is structured as follows. First, Section 3 summarizes the methods used in the evaluation study, focusing on details and possible changes from the evaluation protocol as described in Deliverable 8.1 **(eWALL, D8.1)**. The results of the evaluation study are provided in Section 4, focusing on Population Characteristics (Section 4.1), User Experience (Section 4.2), Use of eWALL (Section 4.3) and finally Potential Clinical Effects (Section 4.4). Detailed conclusions of the study are provided in Section 5.

3 Methods

This section describes shortly the methods used in the final demonstration of eWALL. This section serves as a summary of Deliverable 8.1: Protocol for the experimentation in Humans **(eWALL, D8.1)** and focuses specifically on the detailed description of the analysis of results.

This section starts with a summary of the inclusion and exclusion criteria (Section 3.1), a description of the eWALL installation in the four evaluations sites: the Netherlands, Denmark, Italy and Austria (Section 3.2), and a description of the arrangements regarding education, training and support (Section 3.3).

Overall, the evaluation is focused on three main study parameters. The primary study parameters are **User Experience** (described in Section 3.6) and **Use of eWALL** (Section 3.7) and the secondary study parameter is the **Potential Clinical Effect** (described in Section 3.8). All these parameters are related to the use of the system.

As there are three main target populations (MCI, COPD, and ARI) and four evaluation sites in the Netherlands, Italy, Denmark and Austria, some differences in evaluation methods used in the different evaluation sites exists. Section 3.9 summarizes the specific evaluation methods used in each of the clinical sites.

3.1 Inclusion and exclusion criteria

For each group of participants (MCI, COPD, and ARI), characteristics of profile and inclusion/exclusion criteria were defined as follows:

3.1.1 Chronic Obstructive Pulmonary Disease

Chronic Obstructive Pulmonary Disease is defined as "a common preventable and treatable disease, characterized by persistent airflow limitation that is usually progressive and associated with an enhanced chronic inflammatory response in the airways and the lung to noxious particles or gases. Exacerbations and comorbidities contribute to the overall severity in individual patients" **(GOLD, 2015)**. COPD patients included in the study met the following criteria:

Inclusion criteria

- Clinical diagnosis COPD (GOLD stage 1, 2, 3, or 4);
- Stable: i.e. no infection or exacerbation in the four weeks prior to inclusion.

Exclusion criteria

- Unable to read and speak the language of the clinical site;
- Impaired hand function or disorders causing inability to use eWALL;
- Other diseases influencing bronchial symptoms or need of oxygen therapy;
- Refusal to sign informed consent.

3.1.2 Mild Cognitive Impairments

Mild Cognitive Impairment is commonly defined as the onset and potential evolution of the syndrome (clearly beyond age-related symptoms) through which one could transact from healthy ageing to pathological dementia. MCI patients preserve cognitive and functional abilities and this permits them not to be prejudiced with daily activities. The DSM-V refers to this stage as mild neurocognitive disorder. Inclusion and exclusion criteria were chosen following international guidelines.

Inclusion Criteria

- Age> 65;
- MMSE score (adjusted for age and education) ≤ 24;
- CDR score = 0.5;
- At least a pathological score of 3 in one episodic memory test or in one of other functions;
- Normal scores with all the other battery tests.

Exclusion Criteria

- Age>80;
- Physical impairment that does not allow the proper use of the GUI developed;
- Lack of independence in functional abilities;
- Unable to read and speak the language of the clinical site;
- Refusal to sign informed consent.

3.1.3 Age Related Impairments

The definition of Age related Impairments (ARI) target group is challenging, because it is not connected to a specific medical diagnosis like the COPD and MCI groups. Moreover, it is associated with frailty and pre-frailty, which is not strictly defined and the existing definitions vary considerably. For the eWALL field trials, we aim to involve older adults which face a risk of loss of function in the physical, cognitive or psychological domain.

Inclusion criteria

- Age > 65;
- Short Form 36 score between 0-65.

Exclusion criteria

- Physical and/or cognitive impairment that does not allow the proper use of the GUI developed;
- Unable to read and speak the language of the clinical site;
- Lack of independence in functional abilities;
- Refuse to sign informed consent.

3.2 Description of the eWALL Installations

The four demonstration sites within the eWALL project had some level of freedom in arranging the procedures and installation of the eWALL platform during the demonstration trials. The details regarding the eWALL installation and organizational procedures are described below for the different demonstration sites.

3.2.1 The Netherlands

In the Netherlands, an integrated solution was built that facilitates an easy installation of the eWALL in the home environment, and was aimed to increase the attractiveness of the eWALL overall. In below, the full eWALL setup is shown in the home environment of one of the test participants. The 40" touch screen is mounted with a custom-built construction on top of an IKEA Nornäs cabinet that has 4 drawers and 2 open areas. The PC, all hardware and electronics and wiring are installed in the second top drawer, with connections to the screen, speakers, lamp and Kinect camera hidden at the back of the installation. A connection to a USB Hub is made (through the back) with the top drawer, in which sensors can be charged, and providing easy access and storage for the Blood Pressure and Oxygen Saturation sensor, and wireless keyboard. The bottom drawers are empty, and can be accessed for private use (see Figure 1).

During installation, a technician can mount the screen (using 2 screws on the side of the touch screen monitor), connect the wiring for the speakers, lamp, and Kinect camera. The whole installation is powered by a single power plug. Once installed, the wheels mounted at the bottom of the cabinet and the single-power solution allows the eWALL to be moved and placed at a different location in the home with ease. A wired internet connection can be provided through a TP-LINK AV500 internet-over-the-powerline plug that can be installed near the user's Cable Modem or router.

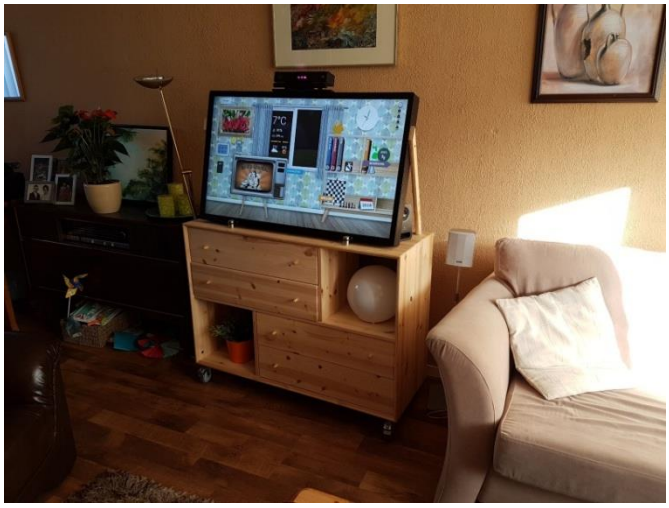


Figure 1: An eWALL in its natural habitat, a home environment in the Netherlands.

An installation procedure at the home of one of the test participants involved a team of one technician for the installation of the hardware, and one medical expert who guided the user through the pre-questionnaires and conducted the pre-interview. Before leaving the user's home, a detailed explanation of the eWALL functionalities was given to the participants (see Section3.3). In case of technical issues, users were asked to contact a phone number that was linked to a mobile phone, operated by one of the six researchers involved in the evaluation of the project, ensuring a high reachability (see Section 3.3).

3.2.2 Italy

In Italy, technical specialists were responsible for the installation of all the devices. The eWALL main screen (32' touch) was mounted on brackets and placed on a solid table. The PC was cabled

taking attention to hide all the cables in the rear of the screen, to guarantee a clean and tidy appearance of the system (see Figure 2). The installation procedure took about 30 minutes, including connectivity and operational tests.

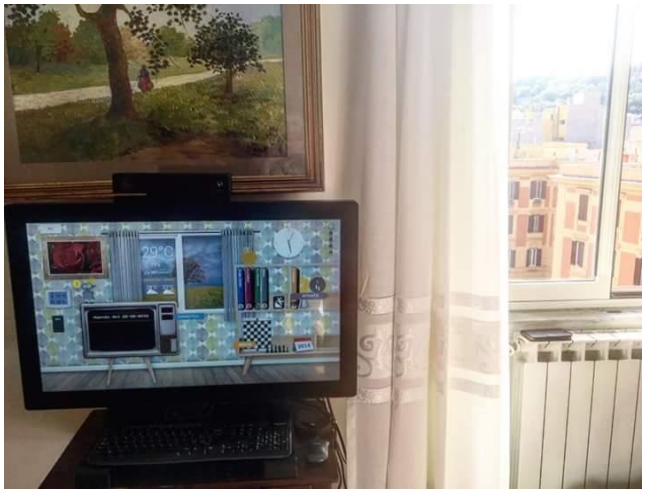


Figure 2:Installation of the eWALL platform in a house in Rome.

The installation team in Italy was made of 4 elements: 1 neuropsychologist, 1 scientific responsible, 2 expert technicians. After a first touch (by telephone), the scientific responsible introduce again the project and the team, and makes clear the objectives of the project, what the patient's involvement means and highlight the chance to stop the participation at any time and for any reason. Firstly an inspection of the house allows to find the optimal space in which instrumentation placement is possible, especially with regards to monitor's size and weight, modem/router location, any other patient's needs. If the internet connection is not present (wired or Wi-Fi), a mobile G4 modem/router was included in the installation kit used. After mounting brackets to the main screen, technicians change the rooms light bulbs with those provided by the Philips Hue kit, than computer and Kinect with the respective cables and Philips Hue Hub are connected. After the installation is concluded, the main procedures to create the eWALL participant account are scheduled. Once a first training is finished (see D8.1 for training procedure **(eWALL, D8.1)**), the participant starts using the platform under the tech's supervision, in order to take confidence with the system and to understand its potential. Finally, the participant wears the Fitbit activity tracker in the correct position (with respect to the wrist) and is warned to be careful of the Fitbit battery state and to recharge whenever it is about to be out of power. At the end of the installation and training procedure, the neuropsychologist interview the participant and leave him/her and the caregiver all the information to contact the responsible of the research, the Ethics Committee or a helpdesk service. In fact, to ensure a proper participation of MCI subjects to the study, a continuous support was provided using a 24/24 and 7/7 helpdesk system, whenever the user or his/her caregiver deemed it necessary.

3.2.3 Denmark

In Denmark, the eWALL installation was built on a stand. The screen itself was placed on the stand. The stand had a small plate on which the keyboard, the internet dongle, the dongle for USBs, and the PC were placed. The rest of the equipment had to be placed next to the installation. The stand itself was assembled in the user's' home by a technician. It took approximately 20-30 minutes to assemble the entire installation.

The organization of the service provision in Denmark was quite simple. The coordinator of the Danish demonstration, PhD fellow Stine Hangaard, was the only person included in the medical side of the project. Stine was also the only person able to speak Danish. Thus, Stine were

responsible for all aspects of the demonstration including recruitment, execution and evaluation of the demonstration. If the participant experienced any issues with their installation, they would contact Stine to report the issue. Stine would then contact the technical partners at AAU who would try to solve the issue. If the issue could not be solved from AAU, Stine would visit the user, often accompanied by a technical partner, to solve the issue. Due to the fact that Stine was the only medical and Danish speaking partner included in the project the demonstration had to be put on hold when Stine was unavailable (vacation or other).

3.2.4 Austria

In Austria, the eWALL screen (42") was installed on a stand to allow its flexible setup in the users' flats. This stand included a little shelf for the additional devices of the eWALL system: keyboard, blood pressure device, pulse oximeter and the charger for the Fitbit wristband (see Figure 3). The screen height could be adapted to the individual user. The PC was cabled taking attention to hide the cables in the rear of the screen. The four sensor boxes for environmental sensing were placed in the rooms (kitchen, bathroom, living room and sleeping room) in a way to be save (cable as a trip hazard) and convenient for the participants. The installation procedure took about 40 minutes, connectivity and operatively tests included.

Figure 3: An eWALL in its natural habitat, a home environment in Austria.

After the installation of the hardware and the configuration of devices, the participants were asked to fill in the questionnaires (see Section 3.6). The following interviews were recorded while the test leader made additional notes coincidently. All interviews and questionnaires with the participants were conducted (and analyzed) by the same person. The participants were then introduced to the eWALL system with all its functionalities and devices (see training methodology in Section 3.3).

Participants had the possibility to call the responsible contact person of ATE whenever they had a problem with the eWALL system. Most of the participants also wrote text messages in case of less urgent issues with the system. Some issues could be solved directly on the phone by directing the participant what to do. In some cases, TeamViewer was used to solve a problem. More complex technological problems were redirected and discussed with the technical contact person in Austria or if needed with the technical partners of the eWALL consortium.

3.3 Education, training and support

All participants of the LSE received information about the aim of the project, followed by a training session at the day of the eWALL installation in their home. The trainings session addressed the eWALL system and its available features by exploring the eWALL system functions. At the beginning, participants were shown the available gestures to be used on the eWALL touch screen (Touch & Tap, Horizontal swipe, Vertical scroll, Drag, Text input). Thereafter, the objects at the

main screen, all applications and the usage of the measurement devices (Fitbit wristband, Nonin pulse oximeter, Omron blood pressure monitor) were explained in detail. This included explanations about the general aim of the applications, the kind of information shown on the screen and how the participant can interpret the data. After completing the training session successfully, the participants were able to use the eWALL system on their own. The procedure of the eWALL user training is described in chapter 5 of D7.7: Education material & training of professionals **(eWALL, D7.7)**.

A particular attention was paid to MCI participants training procedure as subjects with mild cognitive impairment may incur in difficulties to remember how to use the platform. To ensure a proper participation to the project, clinical partners provided continuous support for MCI participants and their caregivers. A specific support service was activated on request using the helpdesk system, whenever the user or his/her caregiver deemed it necessary. Moreover, manuals and clear instructions were provided to participants and their caregivers.

Participants were given the contact details of one Support Person per evaluation site. During the trials, participants could call the Support Person whenever needed. In case of technical problems that could not be resolved by the Support Person, the issue was forwarded to technical partners. From time to time, the Support Person used the TeamViewer to see if the eWALL screen is up and running. In case it was not running for longer period, the participant was called to uncover the reason for not using the system.

For occurring problems, three kind of support actions were taken: Either the problem could be solved by the advice of the Support Person on the phone; Or the Support Person used the access to the user's screen via TeamViewer to analyze where the problem comes from and solve the issue from the distance; If this didn't lead to the expected results, an appointment with the user was scheduled to solve the problem in the user's home.

3.4 Recruitment procedures

The specific recruitment procedures are described below for the Netherlands (Section 3.4.1), Denmark (Section 3.4.2), Italy (Section 3.4.3), and Austria (Section 3.4.4).

3.4.1 The Netherlands

The initial idea was to recruit participants at a physiotherapist, FysioTwente at Enschede. COPD patients often visit FysioTwente to exercise, so it was expected that a lot of these patients would be interested in the eWALL and would be willing to have the eWALL installed in their homes for 5 weeks. Because of the large size of eWALL, a lot of COPD patients hesitated but did not wanted to have eWALL at their homes. To recruit more participants, 42 physiotherapists in Enschede and Oldenzaal were contacted and asked whether they work with COPD patients who might be interested in eWALL. Physiotherapist Wesselerbrink responded and one eWALL was placed in his practice. Since this also did not result in the desired number of participants, another strategy was chosen. An article about eWALL was send to different local newspapers in Enschede, Hengelo and Oldenzaal, which resulted in various publications in local newspapers in Enschede and a news item on the local radio station. A total of 33 COPD patients responded and wanted to participate in this study. A waiting list, consisting of 10 participants who were willing to participate, was created so

when someone drops-out, another interested COPD patient could be called and asked whether he would like to participate and start with the study.

Overall, 21 COPD patients participated in the eWALL study in the Netherlands.

3.4.2 Denmark

The participants enrolled in the Danish trial were recruited through "Hjørring Sundheds Center" – a municipal health clinic. All participants received a letter of information regarding the study prior to enrolment. All participants signed informed consent.

In Denmark we had severe difficulties recruiting participants. We planned to enroll a larger number (n=10) of COPD participants. However, only four COPD participants were included. A large group of patients with COPD (n=25) were invited to participate in the eWALL demonstration. However, only three (four including the drop-out) agreed to participate. The main reason that the patients gave for not wanting to participate was the size of the screen. The second reason was the severe technical issues that the first wave of participants experienced. Due to these recruitment issues we accepted users < 65 years of age.

Overall, 2 COPD patients and 5 ARI subjects were able to participate in this study.

3.4.3 Italy

Due to difficulties of other clinical partners to recruit Mild Cognitive Impairment subjects, IRCCS accepted to focus only on this group. MCI Participants were enrolled through the Day Hospital Unit of the IRCCS San Raffaele Pisana in Rome, Italy. All patients referring a subjective memory impairment were asked to participate the recruiting phase. They received an informative brochure, the system and the protocol were described by trained personnel. The subjects that accepted to participate in the study were further visited and received a neuropsychological screening to assess if they met inclusion and exclusion criteria. Once the subjects who met the criteria decided to enter the study, informed consents were read and signed. Due to the difficulty to recruit such group of patients (MCI subjects are often less confident with digital and ICT devices), a more wide enrolment operation was conducted reaching elderly associations in the area of Rome. 77 subjects were contacted but only 17 accepted to follow the study, 2 of those dropped-out.

IRCCS met the final number of 15 MCI participants.

3.4.4 Austria

The participants of the Austrian trial were recruited through an existing dataset of users. Those people who fulfilled the inclusion criteria were called and informed about the aim and the duration of the trial as well as the system that will be installed in their home. With those who wanted to take part of the study, an appointment was scheduled. After explaining again in detail the study plan, they were asked to sign the informed consent.

Overall, 5 ARI subjects were able to participate in this study.

3.5 Data security, privacy, and ethical issues

In accordance to national and international guidelines (i.e. the Medical Research Involving Human Subjects Act – WMO for The Netherlands, the Italian Drug Agency – Agenzia Italiana del

Farmaco, AIFA through the Osservatorio Nazionale sulla Sperimentazione Clinica dei Medicinali for Italy), during the course of the project the Consortium has taken into account all the laws and protocols for good clinical practice as regards patient safety, data management and privacy rights, and all ethics issues. Detailed discussion is provided in D8.1 and D8.2.

3.6 Methods for evaluation of User Experience

For the evaluation of User Experience, the following three methods were used:

3.6.1 Questionnaire based on the Technology Acceptance Model (TAM+)

User experience and the technology acceptance, were measured by a questionnaire based on the Technology Acceptance Model **(Davis, 1989)**. The TAM+ questionnaire consisted of 34 items which can be divided into 7 domains: enjoyment, aesthetics, control, trust in technology, perceived usefulness, ease of use and intention to use. TAM originates from the 1980s and has been used numerous times to assess and explain the acceptance of new technology. As a result, the core factors that make up TAM are accompanied by summated rating scales that have been validated in many contexts.

For the eWALL evaluation, the TAM model was expanded with factors that determine the user experience of the technology. The resulting complete questionnaire is repeated below in Table 1.

Table 1: TAM+ Questionnaire (modified version of TAM to include user experience.

Original item		Source	eWall item
Enjoyment: "The extent to which the activity of using the computer is perceived to be enjoyable in its own right, apart from any performance consequences that may be anticipated" **(Davis et al., 1989)**			
1	[XXX] was [enjoyable – disgusting]	**(Heijden, 2004)**	eWall was [enjoyable – disgusting]
2	[XXX] was [exciting – dull]		eWall was [exciting – dull]
3	[XXX] was [pleasant – unpleasant]		eWall was [pleasant – unpleasant]
4	[XXX] was [interesting – boring]		eWall was [interesting – boring]
Aesthetics: "Visual beauty or the study of natural and pleasing (or aesthetic) computer-based environments" **(Jennings, 2000)**			
5	[XXX] looks clean	**(Lavie & Tractinsky, 2004)**	eWall looks clean
6	[XXX] looks clear		eWall looks clear
7	[XXX] looks pleasant		eWall looks pleasant
8	[XXX] looks symmetrical		eWall looks well balanced
9	[XXX] looks aesthetic		eWall looks pretty
10	[XXX] looks original		eWall looks original
11	[XXX] looks sophisticated		eWall looks sophisticated
12	[XXX] looks fascinating		eWall looks fascinating
13	[XXX] looks creative		eWall looks creative
14	[XXX] uses special effects		eWall uses special effects
*Control: "The belief that the user can choose to bring about or prevent particular actions or states of the system"***(Jameson, 2007)**			
15	I have a lot of control over what I can do on [XXX]	**(van Velsen et al., 2015)**	I have a lot control over what I can do on eWall
16	On [XXX] you can choose freely what you want to see		On eWall you can choose freely what you want to see

17	I can determine for myself what happens on [XXX]		I can determine for myself what happens on eWall
Trust in technology: "The belief that a technology has protective legal or technological structures (e.g., encryption) that assure that business can be conducted in a safe and secure manner" **(McKnight et al., 2002)**			
18	The security on [XXX] does not set my mind at rest	**(McKnight et al., 2002)**	The security on eWall does not set my mind at rest
19	The law and security technology protect me well against problems with [XXX]		The law and security technology protect me well against problems with eWall
20	Your personal data are protected well when you use [XXX]		Your personal data are protected well when you use eWall
21	[XXX] is not safe		eWall is not safe
Perceived usefulness			
22			Using eWALL helps me to understand my physical condition
23			Using eWall improves my physical condition
24			Using eWALL helps me to understand my quality of sleep
25			Using eWall improves the quality of my sleep
26			Using eWALL helps me to understand the health of my brain
27			Using eWall improves the health of my brain
Ease of use			
28	My interaction with [XXX] is clear and understandable	**(Venkatesh & Davis, 2000)**	It is clear and understandable how I can work with eWall
29	Interacting with [XXX] does not require a lot of my mental effort		I do not have to think hard when working with eWall
30	I find [XXX] to be easy to use		I find eWall easy to use
31	I find it easy to get [XXX] to do what I want it to do		I find it easy to get eWall to do what I want it to do
Intention to use: "A person's intention to use a technology once it is available to him or her"			
32	If [XXX] would be available for me, I would definitely use it	**(van Velsen et al., 2015)**	If eWall would be available for me, I would definitely use is
33	I would recommend [XXX] to others		I would recommend eWall to others
34	I hope that [XXX] becomes available to me		I hope that eWall becomes available to me

For the analysis of results of the TAM+ questionnaire, the following method is used:

- Given scores for question number **18** en **21** are reversed (i.e. 1 → 5, 2 → 4, 3 = 3, 4 → 2, 5 → 1)
- Domain scores are calculated as the averages of the answers:
    - **Enjoyment** = (*Item1* + *Item2* + *Item3* + *Item4*) / 4

- **Aesthetics** = (*Item5*... *Item14*) / 10
- **Control** = (*Item15* ... *Item17*) / 3
- **Trust in technology** = (*Item18* ... *Item21*) / 4
- **Perceived usefulness** = (*Item22* ... *Item27*) / 6
- **Ease of use** = (*Item28* ... *Item31*) / 4
- **Intention to use** = (*Item32* ... *Item34*) / 3

- The total score is the sum of all the individual Items divided by 34 (simple average).

3.6.2 User Experience Questionnaire (UEQ)

Additionally, in Austria, the User Experience Questionnaire was used to analyse eWALL's attractiveness, perspicuity, efficiency, dependability, stimulation and novelty. Attractiveness is defined as pure valence dimension. Perspicuity, Efficiency and Dependability are pragmatic quality aspects which are goal-directed, while Stimulation and Novelty are hedonic quality aspects that are not goal-directed. The 26 items have the form of a semantic differential, i.e. each item is represented by two terms with opposite meanings. Users have to rate each item between -3 and +3 **(Laugwitz et al., 2006)**. This questionnaire is among others available in Italian, Dutch and German language (http://www.ueq-online.org/). To compare the measured user experience of the prototype with results of other products, the UEQ offers a benchmark to classify a product into 5 categories of the 6 scales: excellent, good, above average, below average and bad **(Schrepp, 2015)**.

3.6.3 Open Interview

The open interview consisted of 20 questions (with open answers) about technical issues, personal activity, sleep, health monitoring, domotics, self-management and the general experiences with eWALL.

During the interviews, questions were asked that can be directly related to eWALL (functionalities), as well as more general questions, focusing on getting a picture about the participant's demographics and medical situation. Following **(Patton, 2005)**, we applied Question Analysis (an approach focused on participants' responses to questions, related to specific screens or functionalities of eWALL) for the questions about the technology, and Sensitizing Concept Analysis (an approach focused on concepts that are not interface-specific, such as trust in the system or the intention to use it) for the remaining questions.

The following procedure was used for question analysis:

1. Answers to a question were written out ad verbatim;
2. Two researchers listed the different responses to these questions;
3. Two researchers determined how often each response was given to a particular question;
4. Results were summarized.

In case of disagreements, the two researchers would discuss what would be the best interpretation of a participant's reply until agreement was reached.

For the case of sensitizing concepts analysis, the following procedure was applied:

1. Full interview transcripts were obtained;
2. Topics for analysis were obtained from the interview schema (i.e., the topics of the questions asked at T0, at the moment of eWALL installation);
3. Two researchers listed the different responses for a topic (note that these responses do not necessarily need to be supplied after asking the same question; answers like these can come up anytime during the interview);
4. Two researchers determined how often each response was given on a particular topic;
5. Results were summarized.

Disagreements were dealt with in the same way as for the question analysis. For each question or topic, we reported the different responses and how often each response was given. We only reported responses that were given more than once, so as to keep a clear overview. Please note that although we report exact numbers, they do not imply that one response is more important that the other. In order to determine this, a different study setup would be necessary.

3.7 Methods for evaluation of Use of eWALL

An important objective of the eWALL evaluation study is to assess the Use of eWALL and its individual applications. In order to assess this, an interaction logging service was developed that keeps track of user's interactions with the user interface. The analysis of this data consists of three steps:

1. Filtering raw log data
2. Annotating log events
3. Data analysis

Step 1: Filtering raw log data

The interaction log database was retrieved for all eWALL users participating in the studies. These raw log tables contain a number of oddities and 'false' events that need to be removed. The filtering of instances (i.e. rows in the excel file) concern events that do not regard a true interaction initiated by the user. The following filtering rules are defined:

- All *"login – User logs into eWALL"* instances **that do not directly follow** a "*logoutButton – User taps logout button*" are removed. These 'fake' interaction instances happen to do loss of internet connection and are thus not initiated by the user. Whenever the internet connection is lost, the page automatically "refreshes", causing this login event to be logged. In fact the user did not do anything, so the events are removed.
- Related to the false login events: all *"switchWallpaper1Button"* instances that follow a "*login – User logs into eWALL*" instance are removed. Whenever the system is logged in, the first wallpaper is automatically selected, and this (automatic) event is logged. In fact no user interaction event took place, so these events are also removed.
- All *"passiveModeKinectEvent"* and "activeModeKinectEvent" instances are removed as well as the "*closeGameboard*" and "*closeApplication*" that are associated with the passive mode. Whenever the user steps away from the screen, the user interface will enter "passive mode", which is logged. With this action, there are also some forced "close" events logged

(closeApplication and closeGameboard), in fact these are automatic events that do not involve a true user interaction, so these are removed.

- Some applications log an "applicationLoaded" event when the UI of the application has "finished" loading; this is a software event, or debugging log rule that does not match a real user interaction. All "*applicationLoaded*" instances are thus removed.
- Log events related to applications that are not enabled for the user should be removed. In some rare cases, log events are registered for, for example, the Daily Life application. In some evaluation sites this application was not actually enabled, thus log rules are removed.
- Finally, the log files contain events that relate to the installation and explanation procedure (caused by the researcher before the start of the trial). All events that occur on a date and at a time when the eWALL was not in the user's home, or during the presence of the researchers in the user's homes should be removed.

Note: *we decided to remove all automatic log events caused by the switch from passive to active mode, since we are not sure whether this was caused by the user intentionally stepping in front of the eWALL screen and triggering the switch. By removing these events, we are potentially underestimating eWALL use as the act of walking up to the screen, seeing the current activity level (from the step widget) and seeing the upcoming calendar events (from the TV - teletext screen) actually should be considered a true eWALL use event.*

Step 2: Annotating log events

After the filtering is completed, all remaining log events should be checked and annotated as belonging to the correct application:

- The open- and close-application log rules are originally automatically marked as belonging to the "mainscreen". Therefore, we need to manually annotate "applicationName" field with the actual name of the application.
- The last step of annotation should be to add the column "dayNumber" in which the date values are "converted" to the number of days the user had the eWALL so far. For example, when the user started the eWALL trial on 20-06-2016, that date value becomes "dayNumber = 1", 21-06-2016 = 2, 23-06-2016 = 4, etc… Note that there may be gaps in this numbering if the user did not interact with the eWALL on a specific date. Pay attention at the end of the months (e.g. after 01-07-2017 follows 30-06-2016, but 01-08-2016 does not directly follow 30-07-2016 since July has 31 days).

In the end, this process results in a log event table for each user with the following columns:*evaluationSite*, *userId*, *applicationName*, *buttonId*, *comment*, *dayNumber*, *tzTime*, *date*, *time*.

Step 3: Data analysis

The data analysis of the interaction logs focuses specifically on answering the following four questions:

Question 1: How many times per day does the user interact with eWALL?
The first, and most obvious question is to look at the number of times the user interacts with the eWALL and any of its applications in total, and how this changes in the course of the evaluation period. For this we group all interactions that occur on a specific day (dayNumber) for a specific user, and analyze the data over time.

Question 2: How many times in total did each user interact with each application?
Second, we look more specifically at the individual applications. A very important question for the eWALL evaluations is to see which applications are used. Applications that are used more frequently can be seen as providing added value to the user. For this analysis we calculate for individual users as well as all users grouped together, how many interactions they had with the specific applications.

Question 3: Which applications are used every day, which applications are used sporadically?
It is important to know which eWALL applications are popular to use. When simply looking at the total number of interactions per application, those applications that allow for intensive use (i.e. many interactions in a single session) appear more popular. For a better indication, we look at which applications are used on which day. We count for every user, for every application, and for every day of eWALL use whether or not the application was used. This value is then divided by the total number of days the user was using eWALL. For example, user X used application Y on 94% of the days means that application Y was an app that was used almost every single day (discarding the intensity of use).

Question 4: At what time of the day is it more likely that the user interacts with eWALL?
Finally, we want to gain an insight into when the users use the eWALL and its applications. For this analysis we take a more in-depth look into the times of the interaction events. We calculate for every half-hour of the day, how many interactions with eWALL took place, and report for the total number of users.

3.8 Methods for evaluation of Potential Clinical Effect

The potential clinical effect was defined by several measurement instruments, some of which used in all the evaluation sites, such as the Short Form (36) Health Survey (SF-36) and the Instrumental Activities of Daily Living (iADL), others specifically defined for the various different target populations, such as the Clinical COPD Questionnaire (CCQ) for COPD patients and the Mini-Mental State Examination for the MCI target group. The following list of evaluation methods were used to assess potential clinical effect:

- **Short Form (36) Health Survey (SF-36)**
  The SF-36 was used to assess the perceived quality of life**(Ware & Sherbourne, 1992)**. This questionnaire consists of 36 items, divided into two domains, the physical domain (physical function, role physical, bodily pain and general health) and the mental domain (mental health, role emotional, social function and vitality).

- **Instrumental Activities of Daily Living (iADL)**
  Independent living is assessed by the **iADL (Lawton & Brody, 1969)**. This questionnaire consists of 8 items, ability to use the telephone, shopping, preparation of food, housekeeping, doing laundry and the mode of transportation. This test does not have a cut-off point, it is only possible to compare different measurement moments and conclude whether the participant made progression or deteriorated.
- **Clinical COPD Questionnaire (CCQ)**
  The **CCQ** consists of 10 items and is divided into three domains; symptoms, functional state and mental state and measures the general health status at group level **(van der Molen et al., 2003)**. The lower the score on the CCQ, the smaller the health restrictions.
- **Physical Capacity (6MWT + TUGT)**
  The **6-Minutes Walking Test (6MWT)** and the **Timed-Up-and-Go Test(TUGT)**were used to measure the physical capacity of COPD participants. Per participant, the scores of 6-Minutes Walking Test were compared with a norm score. A score higher than or equal to the norm score is considered as normal. Considering the Timed-Up-and-Go Test, a score below 10 seconds is considered as normal. When a participant scores between 11 and 20 seconds, he or she is frail. When the participant needs more than 20 seconds, further evaluation of the participant is necessary.
- **Mini-Mental State Examination (MMSE)**
  For the assessment of cognitive status, it was decided to adopt **Mini-Mental State Examination** (MMSE)**(Folstein et al., 1975)**, a very common clinical test for the evaluation of disorders of the intellectual efficiency and of the presence of cognitive deterioration, for inclusion criteria and to discriminate on general cognitive condition, moreover, neuropsychological battery tests were included to assessment Episodic memory, Short-term memory, Language, Problem Solving, Attention as described in D8.1: Protocol for the experimentation in Humans **(eWALL, D8.1)**.
- **Warwick-Edinburgh Mental Well-Being Scale (WEMWBS)**
  In Austria, participants were also asked to fill in the **Warwick-Edinburgh Mental Well-Being Scale** (WEMWBS), developed by Edinburgh and Warwick University **(Tennant at al., 2007)**. The WEMWBS is a scale that measures mental wellbeing (as opposed to mental illness or disorder) by covering both feelings and functioning and is suitable for use in the general population **(Stewart-Brown et al., 2011)**.
- **Neuropsychological battery tests (NPS)**
  Neuropsychological battery tests include the assessment of Episodic memory, Short-term memory, Language, and Problem Solving. Specific functions were assessed using different tests:
    - **Episodic memory:** The Rey Auditory Verbal Learning Test **(Carlesimo et al., 1996)**, The Prose Memory Test;
    - **Short-term memory**: Digit Span, Corsi's Test **(Orsini et al., 1987)**;
    - **Executive functions:** Phonological and Categorical **(Capitani et al., 1999)**, Frontal Assessment Battery**(Dubois et al., 2000)**;
    - **Language:** Oral naming Test **(Miceli and Capasso, 2006)**;

- **Problem Solving:** Raven Progressive Matrices **(Basso et al., 1987)**
- **Attention:** Visual Search **(De Wolfe et al., 1999)**, Copy of a drawing **(Spinnler and Dall'Ora, 1987)**;
- **Staging of dementia:** Clinical Dementia Rating Scale (CDR) **(Hughes et al., 1982)**.

3.9 Summary of Evaluation Methods per Country

The following Tables show all measurement moments and the measurement instruments used by the clinical partners involved as reported in D8.1**(eWALL, D8.1)**. The tables below refer to the following four measurement moments during the course of a trial:

- T_0 = Pre-measurement, the day of the eWALL installation.
- T_1 = Mid-term evaluation moment (half-way during the trial period).
- T_2 = Post-measurement, final day and pickup of eWALL.
- T_3 = Follow-up measurement, 6 weeks after T2.

In Table 2 the measurement instruments for the Netherlands are given, in Table 3 the summary for Italy, and in Table 4 the summary for Denmark, and Table 5 summarize measurement for Austria. The evaluation in Denmark was performed using the open interview (Section 3.6.3) and the User Interaction log data (see Section 3.7) only.

Table 2:Summary of measurement instruments used in the Netherlands.

The Netherlands	T_0	T_1	T_2	T_3
User experience:				
Questionnaire based on the Technology Acceptance Model (TAM+)	X	X	X	
Potential clinical effect:				
Quality of life (SF-36)	X		X	X
Instrumental Activities of Daily Living (iADL)	X		X	X
Physical capacity (6 Minutes‘ Walking Test and Timed-Up-and-Go Test	X		X	X
COPD Specific:				
Clinical COPD Questionnaire (C*C*Q)	X		X	X

Table 3: Summary of measurement instruments used in Italy.

Italy	T_0	T_1	T_2	T_3
User experience:				
Questionnaire based on the Technology Acceptance Model (TAM+)			X	
Interviews	X		X	
Potential clinical effect:				
Quality of life (SF-36)	X		X	
Instrumental Activities of Daily Living (iADL)	X		X	
Neuropsychological battery test	X		X	
MCI Specific:				

Mini Mental State Examination (MMSE)	X		X	

Table 4: Summary of measurement instruments used in Denmark.

Denmark	**T_0**	**T_1**	**T_2**	**T_3**
User experience:				
Interviews			X	

Table 5: Summary of measurement instruments used in Austria.

Austria	**T_0**	**T_1**	**T_2**	**T_3**
User experience:				
Questionnaire based on the Technology Acceptance Model (TAM+)			X	
User Experience Questionnaire (UEQ)			X	
Potential clinical effect:				
Quality of life (SF-36)	X		X	
Instrumental Activities of Daily Living (iADL)	X		X	
Warwick-Edinburgh Mental Well-Being Scale (WEMWBS)	X		X	
Additional:				
Sociodemographic data (self-designed questionnaire)	X			
ICT use (self-designed questionnaire)	X			

4 Results

The results section will provide a comprehensive view of the eWALL experience for the 48 subjects who completed the evaluation study. Main characteristics of these subjects will be reported to identify the target of the study, and to allow an easier extrapolation of results to the potential final users of the platform. User experience and acceptance of the systems will be described in detail in the different groups of patients, providing comparative information about different target populations and different countries. Eventually, preliminary data about the potential impact of eWALL on training/rehabilitation programs for MCI and COPD patients, as well as in the group of elderly individuals will be reported, providing valuable information about the conditions which are most likely to benefit by this kind of support.

4.1 Population Characteristics

A total of 48 subjects were prospectively enrolled between April and October 2016 in the four national recruitment centers and participated to the proof of concept study of the eWALL platform, as planned by the final phase of the project. Overall, 15 MCI subjects, 23 COPD patients, and 10 ARI subjects participated the trial based on a prospective design, 15 participants (all MCI) participated in Italy, 21 (all COPD) in The Netherlands, 7 (2 COPD and 5 ARI) in Denmark, 5 (all ARI) in Austria.

Changes in several parameters and conditions from baseline were monitored and measured after the period of home-based intervention, which lasted from three to six weeks. In the following paragraphs, the main characteristics of the study population are described according to the disease group they belong to.

4.1.1 MCI

A total of 15 MCI participants (7 male; 8 female) were enrolled in Italy through the Day Hospital Unit of the IRCCS San Raffaele Pisana in Rome and through associations for elderly people in the area of Rome. Two participants decided to leave the study before the installation of the platform for personal reasons, not directly linked with the experiment. Not surprisingly, considering inclusion criteria, the mean age of MCI participants was significantly higher of the other two groups, The Mini-Mental State Examination was used to identify subjects with subjective memory impairment, mean MMSE value was 23,74. The level of education (namely the years of schooling) and age were used to normalize MMSE. The mean MMSE value reflects inclusion criteria, and the low variability (as shown by the standard error of 1,74) is expected, since patients with lower MMSE values were not accepted when showing traits of a more severe dementia (all subjects had MMSE between 22 and 24). Each participant reported memory impairment, confirmed by a pathological score in at least one episodic memory test. The intervention time slot lasted on average 29,6 days. Table 6 describes main characteristics (±SE) of MCI users' group.

Table 6: Population characteristics for the MCI participants in the eWALL study.

MCI participants	n=15
Gender	7 Male / 8 Female
Age	71,87 ± 0,87
MMSE	23,74 ± 0,09
Education (ys)	16,33 ± 1,74
Days of intervention	29,60 ± 2,74

4.1.2 COPD

A total of 23 subjects (16 male; 7 female) with Chronic Obstructive Pulmonary disease (COPD) were enrolled in two countries, 21 subjects in The Netherlands and 2 in Denmark. Two participant dropped-out in the Netherlands for reasons related to stress experience, 1 patient in Denmark dropped out for reasons not directly linked with the study. Patients were staged using the GOLD classifications to describe the severity of chronic obstructive pulmonary disease. A total of 12 users reported a score from 2 to 4, while for the remaining eleven it was not possible for researcher to access clinical data to obtain the exact GOLD scoring. Patients were on average 66,4 years old. The intervention time slot lasted on average 22,83 days. Table 7 describes main characteristics (±SE) of COPD patients' group.

Table 7: Population characteristics for the COPD participants in the eWALL study.

COPD participants	n=23
Gender	16 Male / 7 Female
Age	65,39 ± 1,72
GOLD staging	From 2 to 4
Education (ys)	15,14 ± 1,06
Days of intervention	22,83 ± 2,13

4.1.3 ARI

A final number of 10 ARI subjects participated the study, among them, 5 subjects were from Denmark (recruited by AAU) and 5 from Austria (recruited by ATE), only one subjects decided to leave the study due to the immaturity of the prototype. Subjects were on average 66,4 years old. The intervention time slot lasted on average 20,10 days. Table 8 describes main characteristics (±SE) of ARI subjects.

Table 8: Population characteristics for the ARI participants in the eWALL study.

ARI participants	n=10
Gender	4 Male / 6 Female
Age	66,40 ± 1,75
Days of intervention	20,10 ± 2,21

4.2 User Experience

As described in Section 3.6, user experience was assessed using several instruments. Mainly, the technology acceptance model questionnaire and open interviews were used.

4.2.1 TAM

As commented in the methods section (3.6.1), the TAM questionnaire will help to determine attitudes of subjects in the target groups to adopt support technologies like eWALL. The

questionnaire has been proposed to study the acceptance of eWALL in different groups of subjects, taking into account several parameters including Enjoyment, Aesthetics, Control, Trust in technology, Perceived usefulness, Ease of use, Intention to use. Main results have been stratified by the condition evaluated (MCI, COPD, ARI), and are summarized through a graphical representation, which provides an easy way to evaluate the information provided by the questionnaire, showing the mean score for each parameter investigated, and allowing an easy comparison between different target groups.

According to the classical model developed by **(Davis, 1989)**, the agreement of responders to the 7 parameters assessed by the eWALL questionnaire were ranked according a 7 items scale, with each subjects attributing a score from 1 to 7, meaning that he/she was extremely, quite, slightly, in agreement/disagreement with the assessment concerning the 7 parameters described above. In MCI participant was decided to add a domain to assess the attitude to the future use of the platform and the willingness to use or recommend the system to others. A score of 4 indicated that the subjects were indifferent to the question, and he/she had no clear opinion about that issue. In the three following tables the level of indifference to the question is highlighted using a red line to make results more clear.

4.2.1.1 MCI

Figure 4 shows the results from the 15 MCI subjects. Results are clearly shifted toward the positive side. Five items out of 8 showed a mean score of 5 or more (the highest was 6.1 concerning a positive attitude towards the system, including the willingness to use it or recommend it to others). The pattern of scores among different items is quite homogeneous (from 4.6 to 6.1), and also the low variability support a general positive attitude of this group, that can be classified as slightly/quite positive.

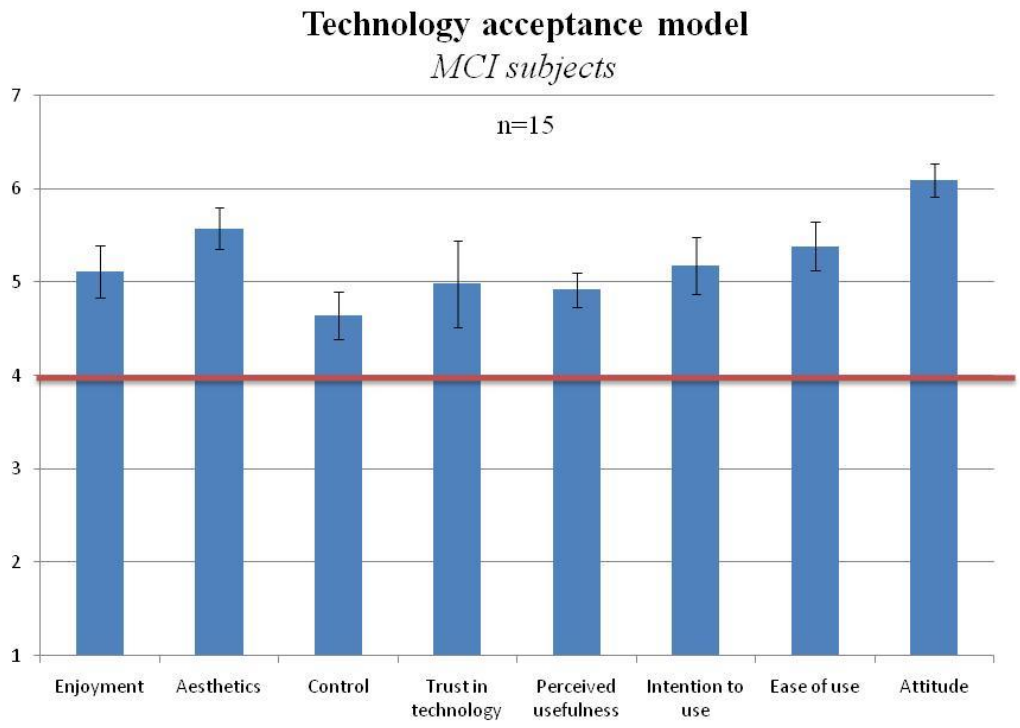


Figure 4 ***:Results from the TAM questionnaire administered to MCI patients***

4.2.1.2 COPD

The TAM questionnaire was administered post treatment to 15 participant out of 23. The pattern of response from the group of COPD patients was slightly different from the group of MCI (Figure 5), but, however shifted toward the positive side. The main attitude in this case could be classified as positive, with scores of single items ranging from 4.4 to 5.6. The distribution of scores according to single items reveals that the ease of use of the system as the item with the highest score (5.6) showing they do not consider the system complex and uneasy to use. The worst result (4.4), though still on the positive side, concerned the perceived usefulness.

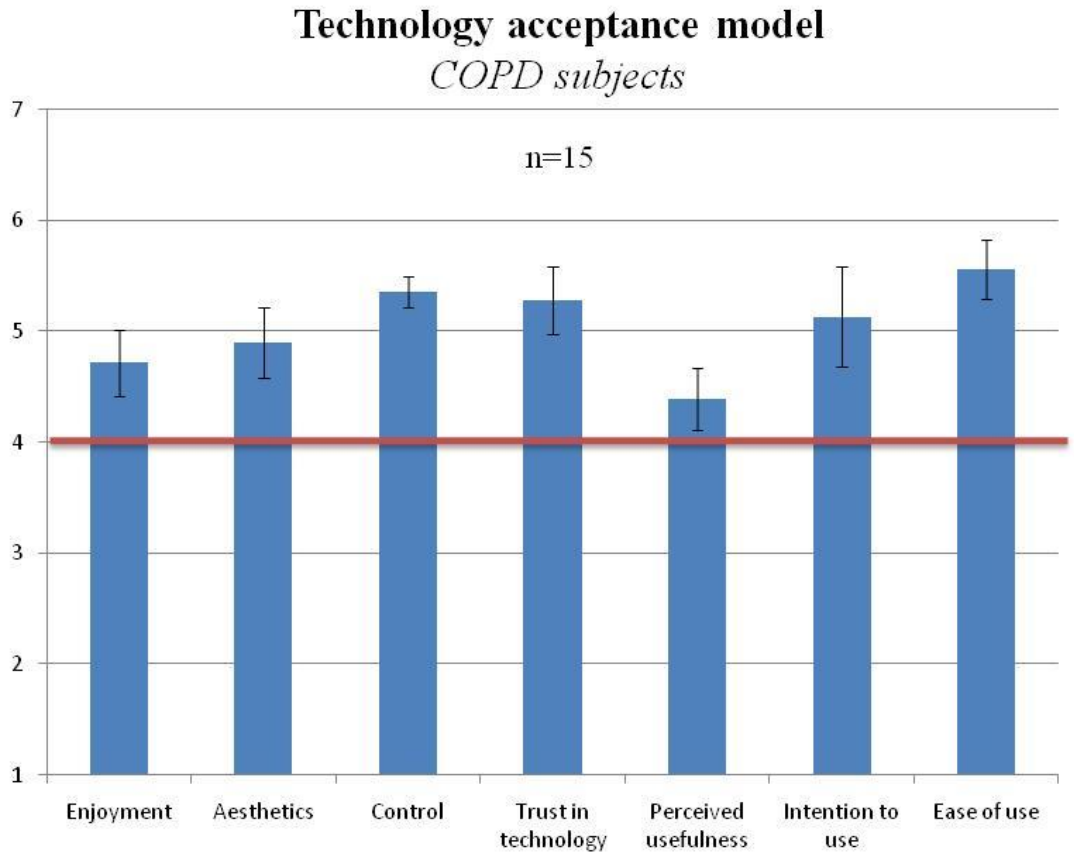


Figure 5 ***:Results from the TAM questionnaire administered to COPD patients***

4.2.1.3 ARI

The results of Figure 6, referring to the groups of ARI subjects, show how globally positive and homogeneous were the responses among the three groups investigated with the modified TAM questionnaire. Interestingly, the items scoring a clear positive level in MCI subjects i.e., the perceived usefulness (4.92), is the item with the lowest score both in COPD (4.4) and in ARI (4.04), which indicates a neutral positions concerning the usefulness of the platform.

This group is characterized by a larger variability of responses, some showing an indifferent evaluation as commented above, other by large on the positive side, i.e., enjoyment, aesthetic, control, and ease of use, with quite positive scores. Not surprisingly, what was the item with the lowest score in the MCI group, i.e., the control over the system, is one of the most positive feature for this group of highly educated, cognitively intact, reasonably well aged individuals (5.7) together, as expected, with ease of use (6.0).

Overall the feeling of this group can be classified as positive. They appreciated some features, while manifested their quite indifference with others, including the thrust in technology and the intention to use this kind of technology.

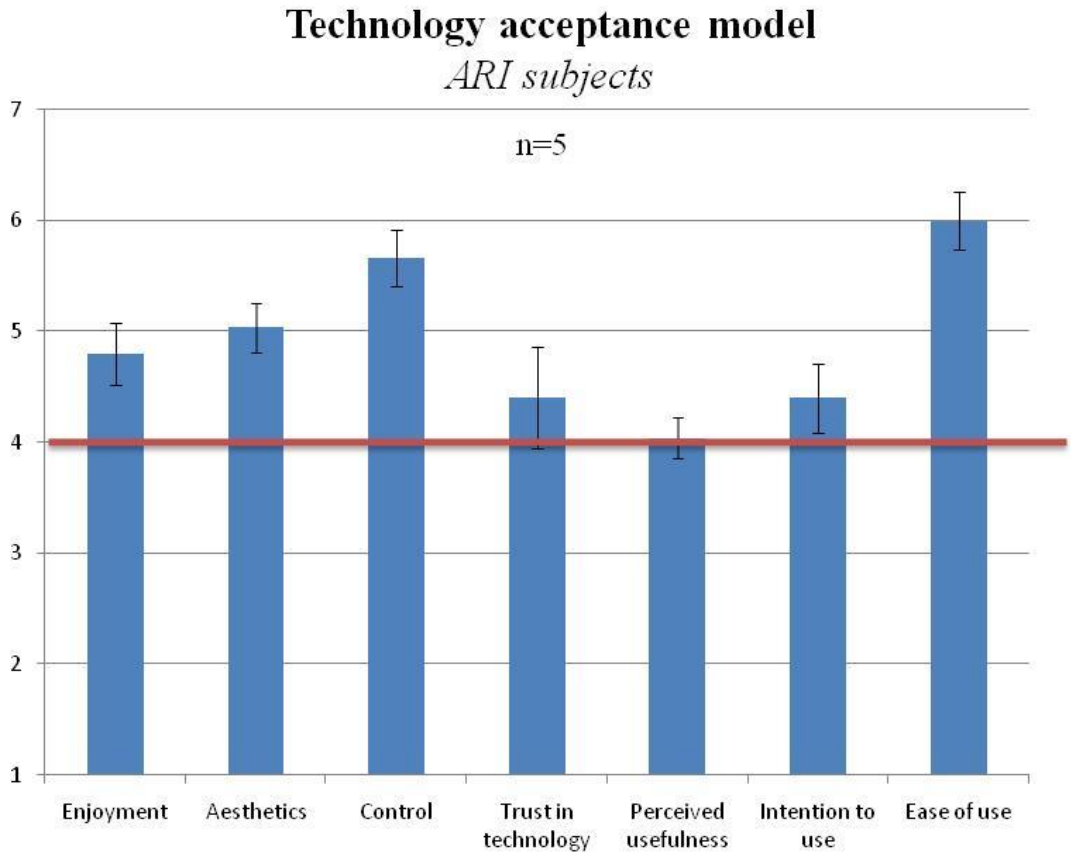


Figure 6 ***:Results from the TAM questionnaire administered to the ARI group***

4.2.1.4 Statistical Analysis of TAM scores

Figure 7 describes the comparison of the three users' groups for the TAM questionnaire scores. Descriptive statistics are reported in paragraphs 4.2.1.1, 4.2.1.2, and 4.2.1.3. The analyses of this parameter did not reveal a statistically significant difference in the acceptance of eWALL among the three different groups. Most likely, the low number of ARI subjects (n=5) contributed to weaken statistical power of the analysis. Nevertheless, the ANOVA of the TAM questionnaire scores showed significant results for the domain *Control* ($F(2, 32)=4.7736$, $p=0.01534$) when the three groups are compared as independent variables. Post hoc comparisons (Bonferroni) confirmed that the perceived control is more critical for MCI with respect to ARI ($p<0.005$). In addition, TAM questionnaire scores showed significant difference for the domain *Perceived Usefulness* ($F(2, 32)=4.7736$, $p=0.01534$) when only MCI and ARI are compared ($F(1, 18)=4.6061$, $p=0.04574$) indicating that MCI patients perceived the importance of the usefulness of the eWALL system for their health status more than ARI.

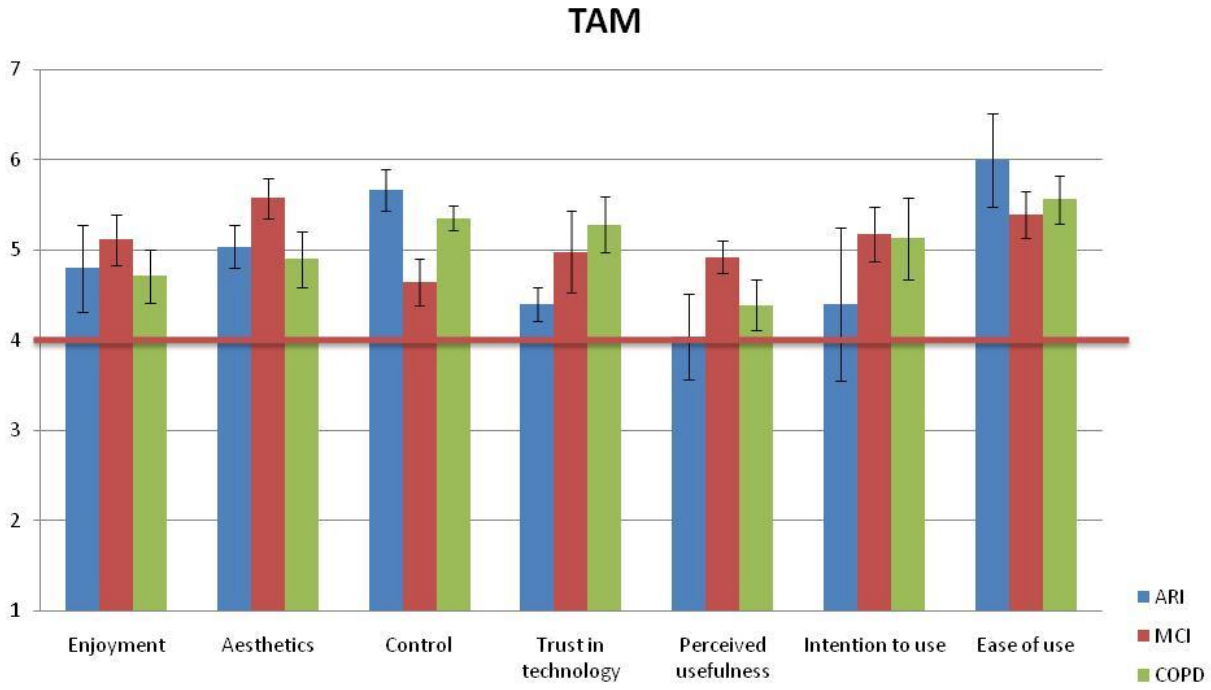


Figure 7*: Comparison among the three group for the TAM questionnaire scores*

4.2.1.5 Longitudinal analysis of technology acceptance in COPD

Researchers from RRD decided to assess a range of user experience factors for eWALL at three different intervals: before, during, and after use in (16 of the 21 COPD users filled in the TAM questionnaires at all three moments). Scores can be found in the Table below. We performed ANOVA analyses to determine whether or not there were differences in scores over time. But for one domain (intention to use, ANOVA: $F(2,18) = 3.793$, $p = 0.042$, Post-Hoc Bonferroni indicated a significant different between pre-test and home visit: $p = 0.011$) no significant differences were found over time (see Table 9).

Table 9:Scores for user experience and technology acceptance factors before, during, and after using the eWALL installation at home (n=16).

Domain	Number of items	Pre-test (Mean (±SD))	Home visit (Mean (±SD))	Post-test (Mean (±SD))
Enjoyment	4	2.48(±1.03)	3.23(±1.17)	3.35(±1.14)
Aesthetics	10	2.48(±1.16)	2.90(±1.30)	3.03(±1.21)
Control	3	2.31(±1.28)	2.94(±1.36)	2.53(±0.71)
Trust in technology	4	2.56(±1.07)	3.17(±1.44)	2.93(±1.31)
Perceived usefulness	6	3.04(±1.09)	3.79(±1.21)	3.73(±1.39)
Ease of use	4	2.77(±1.19)	2.69(±1.36)	2.08(±0.77)
Intention to use	3	2.69(±1.14)	3.86(±1.49)	3.13(±1.81)

4.2.2 UEQ

The following Figure 8 shows the results of the User Experience Questionnaire (UEQ) of the participants in Austria. Giving this analysis a low validity due to the small sample size in Austria (n=5), the eWALL system got a very good rating in all categories, especially for its perspicuity and attractiveness.

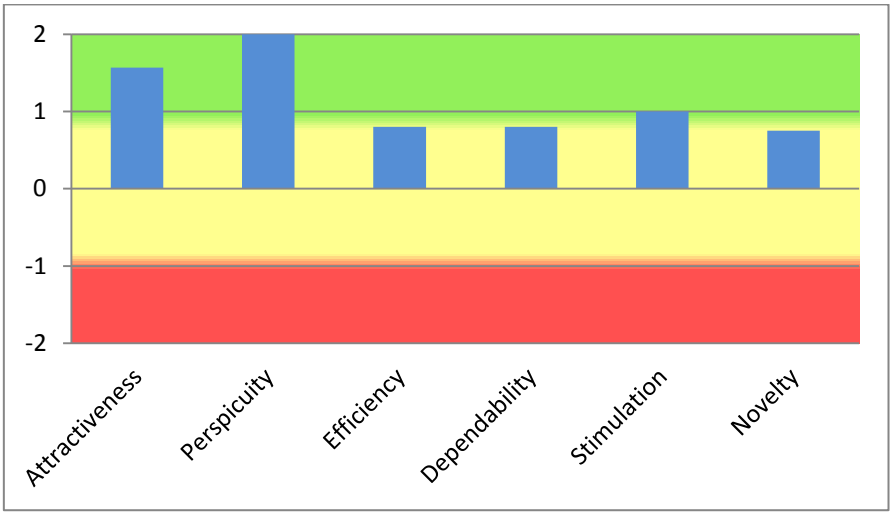


Figure 8: User Experience Questionnaire Analysis of Austrian Users.

The measured scale means are set in relation to existing values from a benchmark data set as offered by the developers of the UEQ. This data set contains data from 9905 persons from 246 studies concerning different products (business software, web pages, web shops, social networks). The comparison of the results for eWALL with the data in the benchmark allows conclusions about the relative quality of eWALL compared to other products (http://www.ueq-online.org/). Figure 9 below shows an **excellent outcome for eWALL's perspicuity, meaning that it is very intelligible and easy to learn**. Compared to other products, eWALL is quite novel to the participants, thus,

creative and innovative. **The participants rate eWALL as very attractive, thus, pleasant and friendly.** Although the test version of eWALL did only have a limited amount of video trainings and games, participants perceive eWALL as above average stimulating. The efficiency of eWALL is perceived as less than average. The lower rating for efficiency could be caused by the technical problems of eWALL, which may also influence the dependability of eWALL, which is below average, meaning that eWALL is quite unpredictable and unreliable.

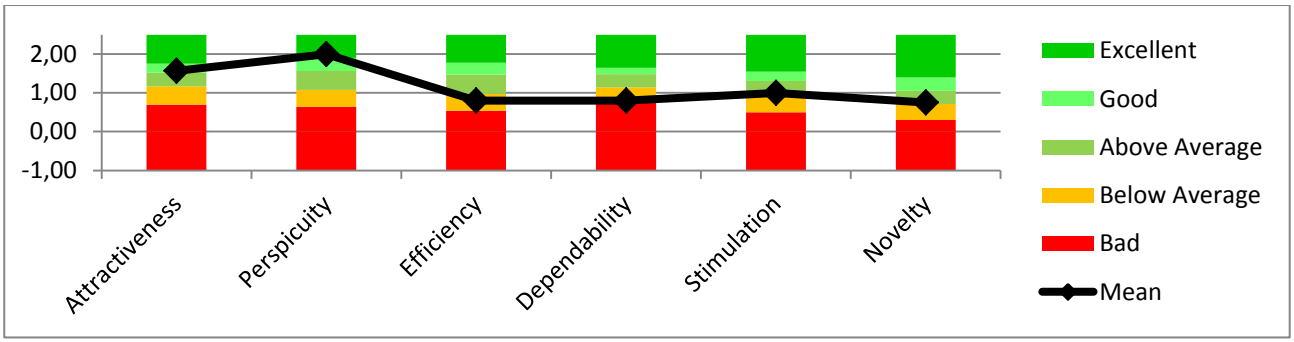


Figure 9: User Experience Questionnaire Benchmark

4.2.3 Interviews

The questionnaire was structured in 10 different topics, addressing complementary issues aimed at describing the interface between the users and eWALL. In synthesis, data collected by the questionnaire investigate the impact of technical issues on the platform accessibility, and the main effect of the eWALL program on everyday life, on personal activity, and on sleep quality. Furthermore, in those centers where all devices were implemented, questions were asked on the feeling about monitoring health data and interacting with the home environment. The last group of questions are about the satisfaction of users about the management of health related issues in the daily life, and how they reacted to wellbeing advertise, and more in general how did they rate the whole experience with the eWALL.

The questionnaire was self-administered and all questions were open, to leave users the possibility to describe in detail their experience. To make possible a comprehensive evaluation of various parts of the questionnaire, and compare different centers or group of patients, the answers to all questions were collapsed to most common answers. In many cases it was quite simple and answers were classified as YES or NO, in other cases a categorical list of answers was assembled from the questionnaires of all centers.

4.2.3.1 Pre-Interviews

Before explaining the participants the usage of eWALL and its functionalities, the clinical staff responsible for the evaluation interviewed the participants to ask them about their daily life, habits, sleep and activity level. In the following paragraphs answers for pre-interviews are summarized for the three user groups.

4.2.3.1.1 MCI

Daily Life

Interests and activities of the participants were different and most of them pointed out the difficulties to lead the daily activities the same as they were younger. All of them mentioned a methodical life like getting up in the morning, having meals and getting out for shopping, walking or other personal business in regular hours every day. Eleven of them performed housekeeping tasks; seven subjects out of fifteen took a walk every day, while six declared to care for their grandchildren for an important part of their days.

For eleven of them health problems or comorbidities affected negatively the daily routine. In addition to experience memory loss, they mentioned the following cases:

1. one of them was forced to interrupt completely physical activity (playing tennis)
2. three of them declared to feel frequently depressed and tired or anxious (fear of falling, fear of driving)
3. one of them had communication problems and difficulties to relate to the others,
4. the other six affirmed to become easily fatigued, to be limited in movements and to need more rest.

Physical activities and hobbies

A total of 8 MCI subjects out of 15 declared that a good physical activity is important but only 5 were satisfied by their physical activity, for the other 3 the weak health status were seen as a main limitation to be active. For 7 participants physical activity was not important, furthermore, 6 of them declared to be lazy and full accustomed to a sedentary style of life.

Hobbies had an important part in the lives of MCI subjects, 12 out of 15 declared to have at least one hobby. The following hobbies list was drafted:

1. Reading 6 times
2. Sport or dancing 6 times
3. Watch TV 5 times
4. Using their own PC 3 times
5. Cooking 3 times
6. Crochet or sewing 1 time
7. Travels 1 time
8. Gardening 1 time

Cognitive Training

Of all the participants, eight out of fifteen trained their cognitive functions, mainly by means of crosswords, puzzles, solitary games using PC or cards. Five out of eight were satisfied, the remaining three would like to do more. On the other hand, seven subjects out of fifteen did not train cognitive functions; among them, four subjects would learn or have the possibility to do more cognitive activity.

Sleep Quality

Six subjects out of fifteen declared to have sleep problems, the main sleep problems were:

1. Anxiety and fear of the dark 1 time
2. Poor sleep quality and daily drowsiness 2 times
3. Frequent nocturnal awakenings 3 times

Two of them solved sleep problems applying a pharmacological strategy.

For nine subjects out of fifteen there was no sleep problem. However, two out of nine declared to sleep too much.

Health Monitoring

Nine subjects out of fifteen complained about issues that would need support.

1. Memory impairment 3 times
2. Pains 2 times
3. Thyroid problems 1 time
4. Fear of falling 1 time
5. Verbal communication problems 1 time
6. Tachycardia 1 time

The other six subjects perceived not to need support for their health.

Twelve participants declared to measure several health parameters, or at home or with their GP; eight of them only to monitor general health status, four of them to follow up a specific health status (hypertension, previous cancer, respiratory problems, previous stroke).

Specifically they stated to measure:

1. Blood pressure 10 times
2. Glycaemia 3 times
3. Cancer biomarkers 1 time
4. Hearth rate 1 time

Three out of fifteen declared not to need to measure any health parameter.

One participant would have the possibility to measure frequently SpO2.

Influence of Weather

Six participants out of fifteen indicated not to be interested by weather or domotic information. The remaining nine declared to be interested in temperature, four of them also in humidity values as these parameters can influence the health status (three times), or to choose how to dress not to risk to take cold (three times), or to manage the air conditioning inside the house (three times).

However, eleven subjects out of fifteen thought it is important to get information about weather conditions or climate inside the home.

Self-Management

Seven participants were very satisfied about their self-management. Seven participants indicated that they do whatever they can to be satisfied about self-management.
The following field of daily life were indicated as difficult to have a control over:

1. Physical activities 4 times
2. Cognitive activity 3 times
3. Socialization 2 times
4. Go out without being accompanied 1 time
5. Help the spouse 1 time

Six out of fifteen declared not to have any problem about self-management.

Expectations of eWALL

The expectancies of the participants were very different. The following arguments were indicated:

1. eWALL will be useful to think more to myself 2 times
2. I don’t know 3 times
3. Gain more control of my health status 3 times
4. Gain more control of my personal life 3 times
5. Participating for science 2 times
6. Improve my communication skills 1 times
7. Improve my cognitive skills 2 times

Five participants expected changes in their daily routine, while three participants did not. Seven participants out of fifteen had no idea about what to expect from eWALL.

4.2.3.1.2 COPD

Daily Life

The daily lives of the participants differed from person to person. Some activities, however, were mentioned frequently. Of the twenty-one participants, seventeen mentioned regular activities like

eating, showering, etc. Resting also took up a significant part of the day for thirteen persons. Another eight persons also performed housekeeping tasks; eleven persons regularly went shopping. Twelve of them were physically active during the day (mainly taking a walk, or walking the dog). Five persons did paid or volunteer work, and four persons watch their grandchildren. Participating in social activities was mentioned four times.

Physical activities and hobbies

The participants had a wide range of hobbies, including mental exercising (e.g., crossword puzzles), working on their computer, gardening, crafting, and participating in sports.

Sixteen participants indicated that they had to give up at least one of their hobbies, due to their health. Their reasons for this were a fear of negative consequences (mentioned once), lower stamina (mentioned 6 times), shortness of breath (mentioned 5 times), overall health decline (mentioned 3 times), and too much dust (as a part of bird keeping).

Five participants did not participate in sports or physical training. The remaining nine persons performed the following sports and/or strenuous activities:

1. Fitness at physical therapy office (9 times)
2. Cycling (3 times)
3. Walking (3 times)
4. Running/cross trainer (2 times)

When we asked them how important physical activity was for their health, the far majority (eighteen participants) told us that it is important. Their reasons were very diverse. Reasons that were mentioned more than once were to prevent further progression of their disease (3 times), to increase stamina (3 times), and to have a good physical condition to fulfill daily tasks, such as playing with grandchildren (2 times). These results are in line with the participants' satisfaction with the current amount of physical activity they get. Fourteen persons were happy with this amount, while six were not. If anybody wanted to change this, they mostly mentioned they would like to do more (diverse) activities (5 times).

Cognitive Training

Of all the participants, thirteen trained their cognitive functions, mainly by means of Sudoku's and crossword puzzles (nine participants). Regarding their satisfaction with their memory, nineteen participants replied that they were happy with how their brains were functioning, while two were not. One of the latter had brain damage, which he could not repair, while the other wanted to improve his memory.

Sleep Quality

Eight participants indicated they had trouble sleeping, for thirteen persons this was no problem. Next, for eleven participants, improving the quality of their sleep was something they would like to do. However, many of them thought it was something you cannot do anything about (3 times) or did not know how to solve this problem (4 times). Six participants stated they did not want to improve their sleep.

Health Monitoring

Seven participants measured vital signs at home, five of them measured the blood pressure and three participants measured oxygen saturation. Participants measured the oxygen saturation and/or blood pressure because they were curious (1 time), because their wife also measures the vital signs (1 time) or because they liked to have physical control (5 times). The following arguments were used when participants explained why they did not measure vital signs at home:

1. The participant feels fine (5 times)
2. The participant knows his/her health status (3 times)
3. The participant does not have the measurement instruments (5 times)
4. The participant does not know why to measure blood pressure and oxygen saturation (1 time)
5. Never measured before (1 time)
6. The more measurement instruments, the more health problems you have (1 time)
7. Blood pressure and oxygen saturation levels are fine (2 times)
8. The participant goes to the physiotherapist or the general practitioner to measure vital signs (2 times)

Influence of Weather

Nineteen participants indicated that humidity influences their health status negatively. Participants changed their activities of daily living (6 times), took more time for all activities (3 times), turned-on the air conditioning (5 times), took an extra Ventolin (2 times) or stayed inside (3 times). Three participants indicated that they did suffer from humidity, but they did not change their behavior.

Self-Management

Seven participants are very satisfied about their self-management. Three participants indicated that they do whatever they can so they have to be satisfied with the result.

Of all participants, six participants indicated they have problems with controlling their general health (three participants), controlling respiratory distress (three participants) and eating healthy (two participants), smoking (one participant) and being active (one participant).

Expectations of eWALL

The expectancies of the participants were very different. The following arguments were indicated:

1. eWALL registers everything, no action is needed (2 times)
2. Based on the activities, eWALL or a physiotherapist can give advice (2 times)
3. Participating for science (7 times)
4. Gain more insight into the health status (mainly respiratory distress) (4 times)
5. Improvements of medications or exercises (5 times)
6. Getting more active (2 times)

7. No expectations (5 times)

Nine participants expected changes in the pattern of their activities of daily living. Participants expected to get new exercises at the physiotherapist (1 time), improve sleep and getting more energy (1 time), becoming more active (4 times) or being watched (1 time). The participants who did not expect changes in the pattern of their activities of daily living indicated that they have a busy schedule, that it is about gaining insight and not about a change in the activity pattern (1 times) and that participating cannot harm them so they did not know why to refuse (2 times).

4.2.3.1.3 ARI

Daily life

All of the participants were already retired and did get up in the morning around 6 to 8 am. Two of the participants were going to a club for seniors several times a week where they meet other others and do certain activities like playing cards. One participant works as a volunteer for two charity organization. One participant visits a school class every Thursday to read together with kids and on Fridays she teaches her daughter-in-law and her grandchild German. Two participants regularly go to the theatre or visit friends. All three female participants do physical exercises at home regularly. All participants perform housekeeping tasks like cooking or shopping. Four of them are physically active during the day (mainly taking a walk, cycling or walking the dog).

Physical activity and hobbies

The participants had a wide range of hobbies, including theatre visits, gardening, travelling, taking care of grandchildren and going for a walk. Three out of the five participants indicated that they had to give up at least one of their hobbies, due to their health condition. Their reasons for this were pain in legs after longer physical activity (mentioned two times), restrictions due to an artificial knee joint (mentioned once), dizziness (mentioned once), problems with breathing in winter (mentioned once) and fear of injury due to fragility (mentioned once). Due to this, two participants reduced their amount of physical activity.

All participants mentioned that regular physical activity is important to them. Nevertheless, one participant cannot motivate himself to do any sport. Another participant says she is doing far too less sport due to lack of motivation. Four participants do not want to increase their amount of physical activity and say they are fine with their current amount of physical activity.

Cognitive Training

All the participants recognized some kind of decline in their cognitive functions due to their age. They mentioned a reduction of their short-time memory, of multitasking activities and of concentration. They may forget to call someone back (mentioned once) or to have an appointment (mentioned once) or forget their shopping list at home (mentioned once). All of the participants trained their cognitive functions, either by card games and word games (e.g. someone has to find another animal beginning with the last letter of the prior mentioned animal; mentioned two times), by computer games (mentioned two times; one participant plays a program called Neuronation). One participant learns French in a course and also trains it with a French-speaking friend. One participant says by taking care of his grandchildren he is also doing some kind of cognitive training since they ask him about different things and he then tries to explain. Two participants would like to

increase their amount of cognitive training and one participant would like to do more focused cognitive training (not just playing cards etc.).

Sleep Quality

Three participants indicated they had trouble sleeping, for two persons this was no problem. One participant takes daily sleep medicine. For two participants, improving the quality of their sleep was something they would like to do. However, one of them did not know how to solve this problem since he was already in a sleep laboratory which didn't help him to resolve the problem. Two participants stated they did not want to improve their sleep.

Health Monitoring

Two participants measure vital signs at home regularly: blood pressure (mentioned two times) and blood sugar level (mentioned once). The three other participants measured the blood pressure very rarely only if they were at a health event (1 time) or at a medical check (1 time) or because their partner asked them to measure (1 time). The following arguments were used when participants explained why they measure vital signs at home: participant has new medication (1 times); if participant doesn't feel well (3 times).

Influence of Weather

Only one participant indicated that weather influences his health status negatively (problems with bronchia when cold outside). Information about weather was not that important for the ARI participants, only to decide if they should go somewhere per car or bicycle (mentioned once).

Self-Management

Three participants are (very) satisfied about their self-management. One participant indicated that she often has too little time for all her plans as she is getting slower with all activities. Of all participants, only one participant indicated to forget regular medication intake.

Expectations of eWALL

The expectancies of the participants were very different. One participant thought eWALL would confirm or show up his flaws. Another participant expected a support in everyday life. One participant was just curious about the system. The other participants didn't have clear expectations

4.2.3.2 Post-Interviews

After having eWALL at their homes for some week, participants were interviewed again. This time it was asked to talk about their experiences with eWALL. More specifically, the interviews were focused on: Technical issues, physical activity overview, video training, cognitive training, sleep, health monitoring, domotics, calendar, robot notifications and their general experiences with eWALL. In the following paragraphs answers for post-interviews are summarized for the three user groups.

4.2.3.2.1 MCI

The study group interviewed in Rome by personnel of the IRCCS San Raffaele Pisana, included 15 individuals diagnosed as MCI. Due to the characteristics of this study group, special attention was given to the usability of the system especially as far as technical issues are concerned, and to the effectiveness of eWALL recommendations to influence daily life of these subjects.

Technical Issues

Question 1 about technical issues revealed as 14 subjects out of 15 experienced major technical difficulties resulting in frustration. Technical issues were driven by connection failure or synchronization failure (Fitbit device):

- Seven participants resolved asking immediately for technical assistance;
- Seven participants showed more indifference to the problem, and this led to a limited interaction with technical support and a longer period of inactivity;
- One subject did not experience technical issues.

Effects on daily life

As regards the other critical issue, i.e., what the users felt about the effect of eWALL on daily life, it was observed an increased tendency to declare that eWALL has changed daily routine.

Nine subjects out of 15 declared the eWALL had some effect on their lives.

Moreover, in the following answer about the expectation, 13 participants out of 15 admitted that they would like to see the effect of eWALL on some or all aspects of their life. In many cases question are repeated in a different detail, to investigated patient's attitude from different viewpoints.

Personal activity

Thinking about the last 6/3 weeks, 11 patients said that they fund eWALL useful, although 6 reported that the system changed their physical or cognitive daily activities. In the following question 10 patients remembered eWALL encouraged them to be more active, although only 3 of them, in the following question said to have actually increased physical activity. The system was programmed to encourage MCI users to have cognitive training, but only 4 patients out of 15 got the message (thought all of them found enjoyable cognitive exercises).

Surprisingly the encouragement to have proper sleep duration was not received at all, with all 15 patients declaring not to have received any invitation to change sleep habit.

Sleep Habits

Specific questions about sleep gave somehow contrasting results with this latter answers, since most users (13 out of 15) declared to have found interesting or very interesting the info about sleep, either in those with (6) or without (7) sleeping problems.

Almost all MCI patients except one found the information clear and useful.

The last two question concerning sleep revealed as users were satisfied to have the possibility to monitor the duration and quality of their sleep, even if only 1 subject declared to have received benefits from eWALL sleep monitoring.

Health Monitoring and Domotics

The two following sessions, on Health monitoring and Domotics could not be investigated since the platforms installed in the houses of MCI patients in Rome did not contemplated devices to monitor these issues. The questions for these two parts were not administered to participants.

Self-Management

Another critical issue was the penetrance of eWALL in the daily life of study subjects. The answers to these questions are quite contrasting, with a large majority (11 out of 15) of patients satisfied, or at least partially satisfied with managing their daily life and other health issues with the help of eWALL (3 out of 15). On the other hand, when the questions investigated in more detail how much users are aware of eWALL notification and how they are used to organize daily life, only 5 out of 15 users found eWALL notifications visible and interesting, and again 5 out of 15 users said that they organized (even partially) their daily life and health issues with the help of eWALL.

Wellbeing Ads and Robot Notifications

As regards the question about the wellbeing advertise, the attitude was quite positive, with 8 users finding interesting or sometimes interesting targeted tips, and the same proportion reporting that tips fitted something or always with their wellbeing. The information was always clear and useful although only 7 out of 8 users made use of that.

General Experience

Finally, the general experience with eWALL was judged rewarding, stimulating, and interesting, at least partially, by 14 users out of 15. The most positive experiences with the platform were those linked with the monitoring and increasing of physical and cognitive activities.

Preferences were given as follows, it was possible to declare multiple choices:

1. Monitoring physical activities 7 times
2. Use of the technology to monitor the functional status 7 times
3. Monitoring cognitive activities 6 times
4. Increase of the activities (physical and cognitive) 5 times
5. Monitoring sleep cycle 3 times

Not surprisingly, the most negative experience was with the platform instability (9 out of 15). The last question about the favorite application showed two applications at the top of the ranking: Cognitive exercise scoring 8 votes and My activity scoring 7. The complete list of favorite applications was as follows (it was possible to declare multiple choices):

1. My Activity Application 8 times
2. Cognitive Exercise Application 7 times
3. Calendar Application 4 times
4. Sleep Application 4 times
5. Fall Prevention Application 1 times
6. Video Exercise Application 1 times

Perceived changes in cognitive status

The last item of the questionnaire refers specifically to MCI patients, reporting results of a Likert-type scale (14 items) focused on the agreement about the benefit that these patients may have had benefits from the use of eWALL. In the large majority of cases the mean scoring of 3, which

indicates no change, confirms the limited impact of the system in such a short period of time. Nevertheless, while most patients indicated 3 in most items, there was a subject which indicated 5 there times and 4 two times, with a total score of 3.6, which confirmed the presence of heterogeneity and the potential presence of subgroups of responders that may be worth to investigate in more detail.

In conclusions, the results of this questionnaire in the IRCCS, MCI patients confirmed as technical issues are critical. Users, especially MCI users feels frustrated by the platform instability, and their positive attitude towards the systems may be spoiled by this problem. Besides this critical limitation, MCI users demonstrated great expectations about the system, with 11 subjects expressing their hope that eWALL will improve their daily life. Users realized that eWALL was asking them to do more, although they admitted not to have followed (for several reasons, including physical incapability) recommendations. Questions about sleep shows that in general users found interesting monitoring their sleep, but were not really interested in the results of the monitoring or in changing their habit. The results concerning the ranking most appreciated applications showed as the degree of interaction is a critical issue to have users involved and participating. Finally, as far as MCI are involved the Likert scale revealed as the presence of heterogeneity among users in the level of participation, and as a consequence, of perceived benefit should be considered and systems designed to be extremely flexible and tailored on individual needs.

4.2.3.2.2 COPD

Technical issues

After a period of using eWALL, we asked the participants firstly what technical issues they ran into during the past weeks. They mentioned a myriad of issues, but the following were mentioned more than once:

1. Fitbit measures incorrectly (steps, stairs, sleep, calories) (12 times)
2. Bluetooth devices do not synchronize with eWALL (11 times)
3. eWALL freezes (4 times)
4. eWALL is very slow (3 times)
5. Fitbit does not synchronize with eWALL (7 times)
6. eWALL loses its Internet connection (4 times)

Physical activity overview

First, we asked participants whether or not they noticed any differences with regard to their daily routines or activities. Fourteen participants said they did not. Most of them (six) thought eWALL only functions as a tool for registration of activity and vital signs, and therefore they stayed true to their regular routines.

Physical Training

Fourteen participants informed us that eWALL did not ask them to be more physically active. Six persons informed us, it did. In this case, they either tried to move more (3 times) or did not follow

up this advice because the person was not physically able to (2 times) or because it was not possible at that moment because the participant was busy (1 time).

Cognitive Training

Ten participants indicated that eWALL asked them to play more cognitive exercises. However, none of them did something with this information, because the participants did not suffer from cognitive problems (3 times), eWALL was too big so they did not like to play games (3 times), the games were not very interesting (2 time), the participant did not have time to play games (3 times) or the participant did not want to play games (3 times).

Sleep overview

Fourteen participants mentioned that it was very interesting to receive information about sleep. Only one participant tried to improve his sleep, based on the information given by eWALL, but this did not succeed. The twelve participants who mentioned they did nothing with the information indicated that eWALL is nice, but it has no influence on behavior (4 times) and two participants said that the sleep pattern cannot be changed by receiving information about the time you went to bed.

Health Monitoring

Eleven participants measured the blood pressure and ten participants measured the oxygen saturation. However, the data was never available on the screen for any of the Danish COPD users. The participants measured these vital signs because they were interested (9 times), because they use this information while exercising (1 time), because they want to check their health (2 times) or because someone told them to do this (1 time). Four participants did something with the information about the blood pressure or saturation. Three participants behave more calm when the blood pressure or saturation is not okay and one participant does breathing exercises.

Six participants indicated that the overview of the blood pressure and oxygen saturation on eWALL is nice. Two participants were rather negative, the information is nothing new (1 time) and dull (1 time).

Self-Management

Fifteen persons answered our question on whether or not eWALL helped them with keeping their condition under control and maintaining their health. Nine of them indicated that eWALL did not aid to these goals. Four of them mentioned that eWALL only provides information, but does not lead to concrete actions. Six of them were positive on this front. Five of them told us that eWALL increases awareness about their physical condition and current disease status. Four persons also mentioned that they became more physically active because eWALL motivated them to walk more. In other words, they wanted to reach the step goals that they were given.

Robot notifications

Only eleven participants were able to provide us feedback with regard to the messages and alarms they received from eWALL in the form of the Robot avatar. Three of them were negative, saying that the content of the messages were quite meaningless and irritating. The other eight persons were positive, mentioning that it was a fun way to interact with eWALL (2 times) and that the messages

were correct and lead to concrete actions on his part (4 times). Two persons were shocked by the message that he was running out of oxygen.

General experiences with eWALL

When we asked participants at the end how they experienced the time with eWALL in their house, eleven of them were positive, saying that it increases one's awareness about his or her health and disease (5 times), stimulates to become more physically active (1 time), and that it is good for one's health (1). Four persons were negative. They said it did not fit with them as a person (1 time), they did not get something out of it (1 time), or that there were too many technical flaws (2 times). Two persons were unable to answer this question.

When we asked the participants for their most positive experiences with eWALL, they gave us the following answers:

1. Registration of their sleep (5 times)
2. Registration of saturation and blood pressure (5 times)
3. Registration of physical activity (4 times)
4. Web-based exercising (1 time)
5. Positive encouragement for a healthy lifestyle (1 time)
6. Becoming aware of one's health (5 times)
7. Having a goal to work on (1 time)

We also asked the participants for their most negative experiences with eWALL. As a response, three participants could not mention anything. The other participants gave us the following list:

1. Problems with synching data from Fitbit and measurement devices (8 times)
2. eWALL does not work at all (7 times)
3. The screen is too big (5 times)
4. eWALL does not have enough functionalities (2 times)
5. The eWALL interface looks old-fashioned (1 time)
6. The Fitbit bracelet is uncomfortable (1 time)
7. It is not possible to turn off eWALL (1 time)

Finally, we asked the participants to define their favorite function(s) of eWALL. One participant inclined that he likes all of the functions of eWALL, the rest of the participants mentioned the following functions:

1. Blood pressure (8 times)
2. Oxygen saturation (3 times)
3. Activity data (number of steps) (10 times)
4. Sleep data (5 times)

5. Heart rate (1 time)
6. Sudoku (as part of the cognitive exercises) (1 time)
7. Agenda (1 time)
8. Physical exercises (1 time)

4.2.3.2.3 ARI

After having eWALL at their homes for some time, we interviewed the participants again. This time we asked them about their experiences with eWALL. More specifically, we focused on: Technical issues, physical activity overview, video training, cognitive training, sleep, health monitoring, domotics, calendar, robot notifications and their general experiences with eWALL.
After a period of using eWALL, we asked the participants firstly what technical issues they ran into during the past weeks. During a first period of intervention with one participant, the following technical problems occurred which caused the deinstallation of the system after the second week since the participant did not want to use it anymore:

- Domotics measurements did not work
- Health measurements did not synchronize with eWALL
- Scroll bar did not work (e.g. in calendar app)
- Sleep app didn't work
- Fitbit shows wrong times for going to bed and waking up
- Whole eWALL system didn't work after 7 days – display shows "strange things"
- Internet connection doesn't work

Even though the participant couldn't really test the system, she liked the video trainings and the domotics app to see a trend of the data over time. The games were a bit boring for her since the questions in the quiz were always the same.
The participant wished to have in eWALL the possibility for online shopping. She would like to order groceries or clothes online over the eWALL screen. Additionally, she would like to have more noticeable alarms for her calendar reminders. She didn't understand the benefit of having the active and passive screen mode and wished to have just a black screen when not interacting with the system as the brightness of the screen was very annoying.

In summary, eWALL did not have any positive effect on the participant due to the technical problems but she would be interested in some of the functionalities that eWALL offers. She misses some more intelligence of the system e.g. that eWALL tells her to dress warmly in case the weather is cold.

Technical issues
Compared to the intervention period of the trial, the eWALL system was much more solid in the following second installations and thus the participants experienced less technical problems. Nevertheless, the following technical issues were reported:

- Fitbit does not synchronize with eWALL (could be fixed)
- Thermostat in kitchen doesn't work anymore

- After software updates the synchronization of pulse oximeter doesn't work anymore
- Weather data do not show exactly the right information
- Sleep: time for falling asleep and waking up are fine, but the average rates are not correct (both too early)
- Users were unable to log into eWALL
- eWALL loses its Internet connection (could be fixed)
- eWALL is sometimes not reacting to the touch interaction (could be fixed)
- Keyboard didn't connect with eWALL anymore – Calendar usage impossible
- Fitbit did not synchronize with eWALL. The issue was not fixed for the Danish users, and fitbit only synchronized with eWALL for two users for approximately half of their test period
- Fitbit showed wrong time on screen
- Fitbit could not be changed when plugging it to the PC – used normal socket instead
- eWALL froze/stalled to such an extent that they could not use the system
- eWALL did not transfer the blood saturation data steadily
- Some users experienced that the blood oxygen measurement data on the screen did not match the numbers on the finger pulse oximeter
- The users had to press "upload" on the blood pressure monitor several times before the data was uploaded
- Sensor boxes discontinued sending information
- Daily step goal froze in the last days and didn't adapt anymore
- Volume in video trainer could not be changed, which was very annoying

Other issues:

- GUI is very bad (looks like made 20 years ago, not modern concept)
- Some things would be better to do in sitting position, e.g. playing games (mentioned 4 times)
- User should get some feedback or information when or how often the Fitbit data is synchronized with eWALL(mentioned once)
- One participant mentioned that the Fitbit Flex wristband is very difficult to put on. Also the charging of the battery is very difficult for older people.

Physical activity overview

First, we asked participants whether or not they noticed any differences with regard to their daily routines or activities. Three participants said that it motivated them to go for a walk when they sawthe number of steps, especially when they didn't have a lot of steps on that day.One other participant couldn't actually remember that he saw the steps on the screen. The usage of the application was easy for all participants of the second and third period of installation, except for participant who didn't recognize the steps in the overview

One participant could only see the steps on the Fitbit since it didn't synchronize the data with eWALL. Two participants were asked by eWALL to be more physically active. Another participant did not know (anymore) that the robot is showing information to him, thus, he wasn't asked to be more physically active. However, three participants indicated to be more physically active with

eWALL.One participant highlighted that she was so motivated to do more physical activity and lost three kilograms within four weeks.

In Denmark, the activity data were not available for the majority of the users (n=3) and only partly available for (n=2) users. This obviously affected the users' experience of the activity book. The users expressed an interest in seeing an overview of their activity data. Therefore, the lack of available activity data lead to a lot of frustration and dissatisfaction among the users. Even though no data were uploaded, the system would often change/increase the goal of the user during the test period. This was confusing for the users as they were insecure on the meaning of the goal.

Video Training

One participant really liked the video trainings and used it every second day. In his opinion, the difficulty level was alright. He didn't do any exercises before eWALL, so his activity level has been clearly increased by eWALL. The other participant tried the exercises but experienced them too easy and a bit boring.

One subject proposed to add some music in the background. The rating of exercises was also annoying for one used as he didn't understand the reason to rate the same exercise every day. One participant mentioned that a new exercise started before she could finish the suggested repetitions of the earlier exercise, thus, the break should be longer. However, all participants really liked the idea of the video trainer – someone who instructs them exercises in a video - but wished to have more variety of exercises and difficulty levels.

Cognitive Training

All participants indicated that eWALL did not ask them to play more cognitive exercises. Two participants played the number game (mentioned 2 times) and Sudoku (mentioned once) regularly, the other games were not that interesting for them. One participant played together with her husband or with visitors. One other participant did not play regularly, as he didn't feel the need to do cognitive training and because the games were a bit too easy and boring, with except to the number game. One participant couldn't play with eWALL since she got low back pain while standing in front of the screen but mentioned that the games would be interesting for her in case she could play in sitting position. Two other participants also wished to play while sitting. The use of the games was easy for all participants. Two participants wished to have also word games (e.g. crossword puzzles), since games with numbers and pictures are already included. One participant wished to have bar charts to see her progress in the games as this would be very motivating for her.

Sleep

The sleep application was, beneath the physical activity overview, the most interesting functionality for three participants. However, two of them were not available to see their sleep data on the screen for technical issues, which obviously caused dissatisfaction. One participant was very enthusiastic that the system recognized his sleep data so well. Two participants couldn't use this functionality due to some synchronization problems. In case it synchronized, the time was not right (e.g. showed that he went to bed at 6 am and got up at 3 pm) so this functionality was not used anymore by this participant. However, this participant would use the functionality if it works correctly. He would

like to have also more direct stimuli to go to bed earlier. In general, this application was very interesting for those participants who could use it, especially when participants had sleep problems.

Health monitoring

All participants reported technical problems with the synchronisation of their health measurement devices. In Austria, five participants reported technical problems with health measurement devices synchronization. One system didn't transfer data from the blood pressure device or from the pulse oximeter. The other system did just transfer the blood pressure data. Nevertheless, all participants could see their data on screen of the devices. It was then very interesting for the participant to see the overview of his values over time and he reacted to this information changing some behavior. All participants indicated that the overview of the blood pressure and oxygen saturation on eWALL is/would be nice (in case it synchronizes the data). One participant recognized through eWALL that her blood pressure is slightly too high and planned a medical check-up. The participant appreciated that eWALL helped her recognizing this but emphasized the importance of valid measurements and correct synchronization to be able to build up a level of trust in the eWALL system. All participants liked the presentation of data in the health application and found it easy to use. One participant was curious how long the date would be stored in the system and thinks that it should be at least six months to have a good overview.

In Denmark, the users' experience of the My Health book was influenced by the instability of the transfer of data. The health data was not available at all for some users and only partly available for the remaining users. In general, the users expressed a great interest in seeing an overview of their health related data. Obviously, the lack of available data therefore caused a lot of frustration and dissatisfaction among the users. One user described that she had taken one blood pressure measurement that she did not wish to upload. She waited a while and did a new measurement and pressed upload. However, the first measurement appeared on the screen which she found annoying. The same user sometimes did several blood pressure measurements on the same day. When she then looked at the weekly/monthly overview it was unclear to her if the system presented an average of the daily blood pressure measurements. One user found the cuff of the blood pressure monitor too large for her arm.

Domotics

The domotics application was not that important for the participants because i) they cannot change anything over the Screen (mentioned once), ii) they know themselves if they feel cold inside, thus, to turn on the heating system (mentioned twice) or iii) the information is not important (mentioned once). Nevertheless, one participant wished to have more direct feedback what to do, e.g. to open the door. One participant mentioned it would be interesting to see combination of the data e.g. which temperature the best for him to have a good sleep. Another participant recognized that the humidity was too low in her house and could see the humidity rising after setting up the humidifier. The GUI was easy and intelligible for the participants.

Calendar

In Austria, the calendar was only used by one participant. Reasons are that i) one participant doesn't have many dates and knows all of them by heart, ii) the keyboard didn't synchronize with eWALL or iii) one participant didn't like the data input with both the keyboard and the touch interaction to scroll down. He would prefer to scroll down also with the keyboard. Two participants also wish to have some kind of acoustic reminder for planned appointments.

In Denmark, the users' employment of the calendar was highly affected by the fact that the users only had the system available for a few weeks. The users already had existing calendars that they would use for their appointments. However, most of the users had a look at the calendar for the purpose of the test. The users found it easy to use – some users thought that it was similar to other calendars which they found positive.

Main Screen

Although in general it was very easy for the participants to navigate through the main screen, the participants had some ideas for improvements:

- Name of books should be written horizontally similar to "ACTIVITY"
- Increase the contrast for the book "My Activity" (e.g. darker yellow)
- The tips to reduce risks should also be in a kind of book
- The brightness of the screen is still too high in OFF-mode
- The design looks very old for the participants who wish to have a modern virtual TV etc. and not that retro style.

Photo Frame: One participant thinks the photo frame should be much bigger if it is for personal pictures. Another participant didn't really notice this photo frame.

Wellbeing Ads: Three participants didn't apperceive the wellbeing ads. One participant noticed them but indicated that he didn't feel motivated by them. One participant disliked the retro style of the wellbeing ads.

In Denmark, the users disagreed a little on the main screen. Overall, the users found the design of the living room meaningful. However, one user found the main screen boring to look at. The users generally found the applications easy to use. They found it quite logical to use when they had the opportunity to try their way around the system. However, most users found the number of applications too high and would prefer a more simple system. On the other hand, one user praised the system for having many applications as he found that exiting.

Robot notifications

We asked the participants to provide us feedback with regard to the messages and alarms they received from eWALL in the form of the Robot avatar. Two participants liked the robot and indicated to be motivated by the messages. One participant also really liked the idea of getting eWALL coins as rewards for physical activity. One participant didn't even recognise the robot and that he had to tap on it to see the messages. Another participant was annoyed because she received messages too often. Further, once a message was not correct as it said "You are running out of oxygen, open the window and breathe."

In Denmark, the users did not express a lot of interest in interacting with the robot. Most of the users did not actively start an interaction with the robot. (n=2) users found it too difficult to close down the robot. Both users thought that it should always be clear how to make the robot disappear. Most users found the robot notifications confusing and misleading. For instance, several users were asked to open their windows due to lack of oxygen even though no sensor was installed that could detect such an issue. Moreover, some users were notified about a high blood pressure even though the blood pressure was actually too low or just right. As an example, one user was notified about a higher blood pressure when his diastolic blood pressure had increased from 124 to 127. This is obviously too sensitive and the user would prefer larger deviation before the system reacts. Otherwise it could cause unnecessary worry among the users.

General experiences with eWALL

In Austria, three participants mentioned that they became more physically active because eWALL motivated them to walk more. Reasons for more physical activity were that they wanted to increase their daily steps or to reach the step goals (mentioned twice), one participant did video trainings regularly.

When we asked the participants for their most positive experiences with eWALL, they gave us the following answers:

- Registration of physical activity (3)
- Overview of blood pressure (2)
- Registration of their sleep (1)
- Games (1)
- Weather forecast (1)

Finally, we asked the participants for their most negative experiences with eWALL. The participants gave us the following list:

- Technical problems in general (2)
- The eWALL interface looks old-fashioned (2)
- The calendar doesn’t have alarm functions (2)
- Robot Robin is annoying (1)

In Denmark, the general experiences of eWALL were highly influenced by the technical difficulties. All of the users were frustrated and dissatisfied with the fact that their data was not available on the screen. This was especially problematic because it was the health data and the activity data that the users showed a particular interest in. Several users described the system as “not working”. One user described that: “Perhaps the interest in using the system would increase if it actually worked“. The users were positive about using the “secondary technologies” such as the blood pressure monitor, the finger pulse oximeter and the fitbit to do their measurements. However, the frustration occurred when the measurements were not uploaded to the screen. All of the Danish users found the screen too big. They found it clumpy, noisy, too bright and inappropriate for a home

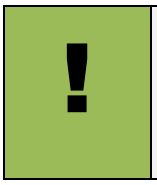
setting. A few suggested a tablet as an alternative. Some users found it confusing to switch on/off the system which caused a lot of problems. It should be easier to start and shut down the system.

4.3 Use of eWALL

The use of eWALL was extensively monitored through an interaction logging service that logged each interaction of the user with the eWALL platform. The analysis methods for this interaction log data is described in detail in Section 4.6: Methods for evaluation of Use of eWALL, and focuses on the four research questions, repeated below:

- Question 1: How many times per day does the user interact with eWALL?
- Question 2: How many times in total did each user interact with each application?
- Question 3: Which applications are used every day, which applications are used sporadically?
- Question 4: At what time of the day is it more likely that the user interacts with eWALL?

Before describing the results that go deeper into the four research questions, a note on the filtering efforts involved in compiling this data. The interaction logging functionality developed in the project was done with a "log everything" approach, something that is undoubtedly useful for (software) trouble shooting. However, when the aim is to get an idea on how users interact with the platform, this causes some issues. The manual filtering approach described earlier was laborious. For example, for the 21 Dutch users, there were a total of 52,864 lines of logged interactions, whereas only 19,288 were left after the filtering phase (64% of all logged data had to be manually removed). Furthermore, each of the remaining log rules had to be annotated manually, which is a time consuming effort. The first recommendation for eWALL's future commercial activity is thus:



Re-design the interaction log service to provide automatic, real-time insights into actual use of the platform and its individual applications.

The following sections go into details answering the four research questions, question 1 is discussed in Section 4.3.1, question 2 in Section 4.3.2, question 3 in Section 4.3.3, and the last question in Section 4.3.4.

4.3.1 eWALL Interactions per day

In order to get a detailed picture of the use of eWALL per user and per day we provide the interaction log data for this in Table 10 below. Due to the space limitation we did not include all days of usage, only the first 14 days.

USER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	…	TOTAL
NL-1	5	0	0	102	15	1	0	0	0	10	18	0	0	0	…	428

NL-2	0	0	7	0	157	15	44	2	40	10	5	32	0	0	…	533
NL-3	282	51	41	80	9	80	41	64	40	25	81	19	0	0	…	1051
NL-4	41	45	0	30	42	55	10	8	6	19	15	30	9	9	…	454
NL-5	91	63	127	101	112	72	38	151	9	18	40	18	106	34	…	1277
NL-6	221	92	76	106	62	78	64	136	27	4	6	182	48	46	…	1828
NL-7	282	158	27	6	0	21	13	0	0	8	32	0	0	21	…	699
NL-8	244	251	94	75	59	41	37	25	25	-	-	-	-	-	-	851
NL-9	75	143	33	59	0	0	0	0	73	35	13	0	42	20	…	1049
NL-10	0	0	53	22	4	30	33	29	42	24	22	78	40	33	…	652
NL-11	134	166	80	0	14	0	18	-	-	-	-	-	-	-	-	412
NL-12	6	19	2	4	19	6	12	3	75	2	24	16	41	6	…	426
NL-13	3	44	28	16	0	0	13	42	14	14	0	0	0	0	…	469
NL-14	101	55	7	0	0	29	0	56	23	22	85	12	0	17	…	1273
NL-15	176	203	62	72	91	52	50	54	21	41	26	44	73	76	…	1781
NL-16	42	110	78	4	0	0	0	49	57	-	-	-	-	-	-	340
NL-17	28	0	131	50	3	4	0	7	0	47	0	0	0	17	…	502
NL-18	102	103	114	71	105	78	68	81	28	21	17	46	37	18	…	1598
NL-19	110	121	137	107	128	180	87	69	95	147	26	51	58	42	…	2893
NL-20	77	236	17	0	13	42	15	25	4	0	11	11	22	6	-	479
NL-21	4	32	63	2	9	19	0	39	0	0	56	29	18	10	…	293
AT-1	6	173	42	38	29	0	122	194	0	322	180	42	14	-	-	1162
AT-2	249	132	104	59	32	269	53	56	69	49	56	156	142	90	…	2753
AT-3	226	91	30	0	28	51	16	57	54	55	12	12	0	0	…	1084
AT-4	104	83	139	110	67	105	70	127	45	81	160	107	64	66	…	2406
AT-5	27	0	0	0	35	19	0	0	0	0	0	22	21	22	…	192
DK-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DK-2	46	18	20	50	17	2	-	-	-	-	-	-	-	-	-	153
DK-3	34	0	6	0	0	0	6	-	-	-	-	-	-	-	-	46
DK-4	4	0	0	4	1	4	21	6	0	0	42	5	7	1	-	95
DK-5	0	0	64	24	26	0	5	0	0	0	82	70	8	18	-	297
DK-6	21	15	24	33	0	0	5	0	9	13	18	3	0	0	…	165

DK-7	102	22	20	33	28	86	14	12	16	0	33	44	0	65	...	487
DK-8	56	0	0	35	2	18	35	14	5	3	2	29	-	-	-	199
IT-1	213	14	98	38	17	0	0	12	21	29	92	14	0	0	...	1181
IT-2	202	55	78	128	97	170	4	95	47	83	33	73	83	100	...	1889
IT-3	43	0	0	0	0	6	110	0	113	152	121	78	20	83	...	1967
IT-4	79	0	0	0	0	0	0	0	0	0	0	0	0	0	...	232
IT-5	51	0	0	0	0	0	0	0	0	0	47	40	0	0	...	346
IT-6	77	15	26	17	5	4	0	17	0	0	6	4	0	0	...	263
IT-7	184	134	56	0	0	82	38	0	45	35	122	121	98	0	...	1590
IT-8	2	0	0	0	0	0	4	0	115	0	37	0	3	0	...	279
IT-9	149	80	192	23	67	49	47	44	29	12	18	61	48	0	...	907
IT-10	85	0	0	136	90	46	0	0	14	29	0	0	0	0	...	407
IT-11	88	4	0	0	0	0	0	0	0	39	4	0	0	3	...	341
IT-12	142	103	45	120	62	80	81	40	0	155	147	80	80	105	...	1687
IT-13	177	76	64	0	12	53	44	0	56	33	0	4	24	21	...	708
IT-14	76	54	20	28	0	0	3	0	14	2	2	1	0	3	...	203
IT-15	111	0	3	0	0	0	0	12	3	0	3	0	0	2	...	213

Table 10: Number of interactions per user, per day of using eWALL for the first 14 days of the evaluation period.

Some users that chose not to continue with the eWALL evaluation study did not generate a full 14 days of user interaction log data, but for most users, a significant amount of data is omitted in Table 10. However, the last column in Table 10 shows the total number of interactions per participant; the grand total of interactions observed with eWALL during the trial is 40,540. By looking at the days on which users interacted with eWALL we can generate the following "burndown" graph, indicating how many of the 49 users were actively interacting on the n-th day of the evaluation period (see Figure 10 below).

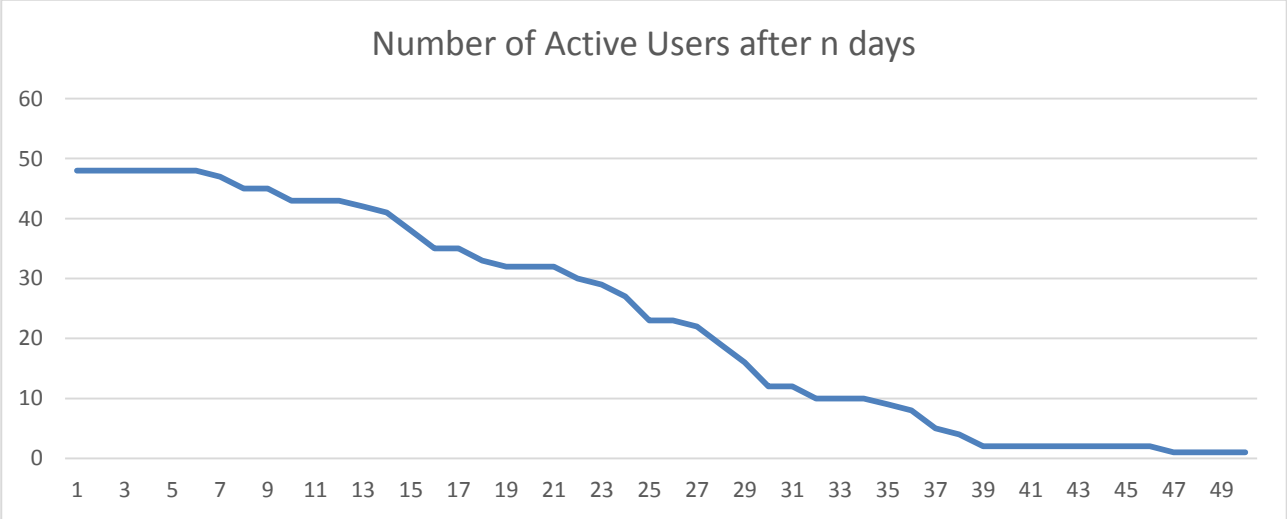


Figure 10: Total number of active users on the n-th day of the eWALL evaluation.

The graph shows that 48 different users had interactions with eWALL on the first day, and kept using the system for the first 6 days. On the 7th and 8th day the first drop-outs occur. After two weeks 41 users were still using eWALL, after three weeks 32 users were still active, and after four weeks the number starts to drop more rapidly to 19.One user was using the eWALL for 50 days.

The question of "how many times per day does a user interact with eWALL" should be answered taking into account the novelty effect of having the eWALL installed in the home for the first time. In Figure 11 the average number of interactions for each of the 50 evaluation days is plotted. From this graph, three important things may be observed:

- A clear novelty effect can be observed from the number of interactions with eWALL. On the first day of an eWALL installation, users have on average 95 interactions with eWALL (±82), which slowly drops down over the first 3-4 days of usage.
- eWALL users show a regular, and stable usage pattern over the course of the evaluation period. The average number of interactions in the first week (47.8) is slightly higher than in the consecutive weeks (due to the novelty effect), but the usage in the second (31.6 daily interactions on average), third (32.7 daily interactions) and fourth week (28.0 interactions) show a very stable pattern of use.
- After the fourth week, usage seems to decline slowly, although this observation is based on a small amount of data as the number of active users that are still active after more than 4 weeks is low (16 on day 29, 8 on day 36).

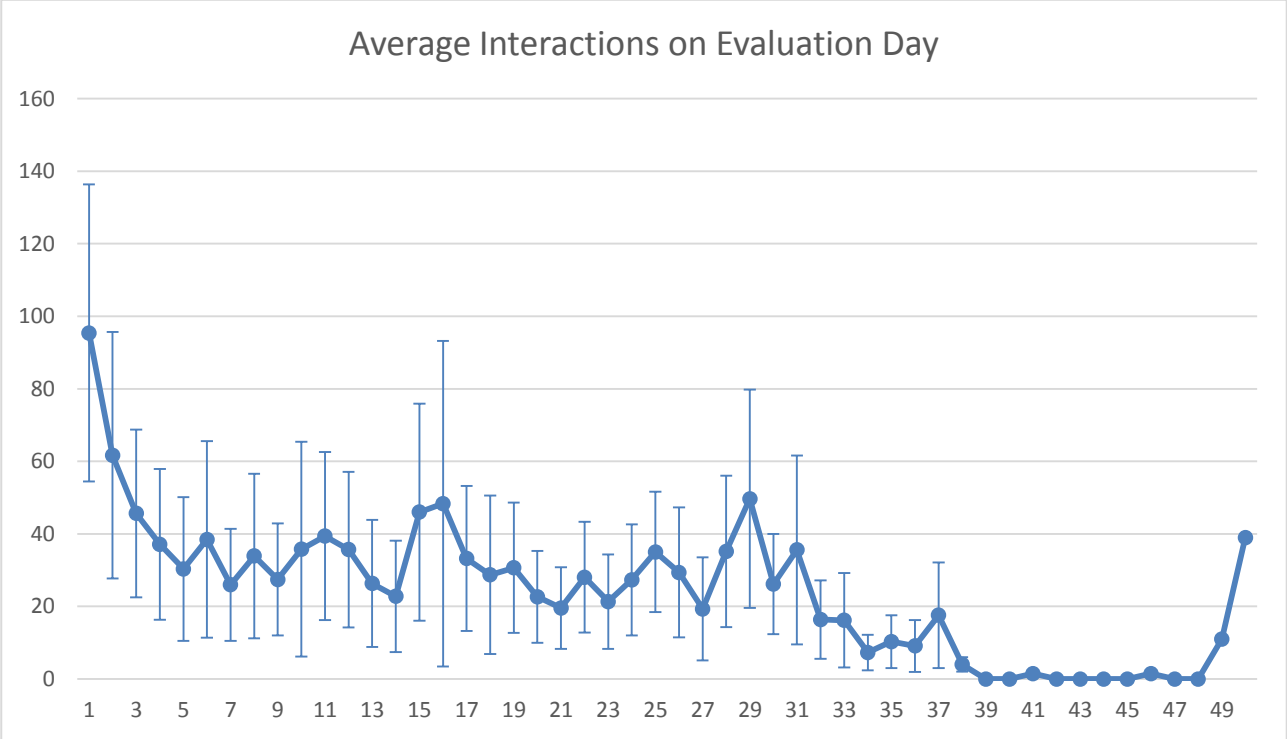


Figure 11: Average number of interactions on the n-th evaluation day (values averaged over all active users on that day).

A short summary of the answer to the first research question would be:

!	**After an initial week of intensive eWALL use (likely caused by the novelty effect), users perform on average over 30 interactions with the eWALL on a daily basis.**

4.3.2 Distribution of application use

One of the major objectives of the eWALL evaluation study is to find out which functionalities of eWALL are most appreciated by the target users. From the interaction logs we can observe which specific applications are being interacted with by the users, as each interaction is "annotated" as belonging to one of 11 categories. In Table 11 the total interactions per application for all eWALL study participants is show (including mean, standard deviations, minimum and maximum values).

Table 11: Total, mean, standard deviation, minimum and maximum amount of interactions per application for all eWALL evaluation study participants.

FUNCTIONALITY	TOTAL INTERACTIONS	MEAN INTERACTIONS	STANDARD DEVIATION	MINIMUM INTERACTIONS	MAXIMUM INTERACTIONS
CALENDAR	2255	46.0	87.8	0	483
COGNITIVE GAMES	5881	120.0	155.7	0	700
DOMOTICS	2139	43.7	80.1	0	457

FALL PREVENTION	401	8.2	9.6	0	46
HELP	422	8.6	18.3	0	100
MAIN SCREEN	3375	68.9	100.4	0	661
ACTIVITY BOOK	8704	177.6	171.1	0	673
HEALTH BOOK	6120	124.9	146.3	0	584
REWARD APP	432	8.8	16.4	0	106
SLEEP BOOK	8874	181.1	161.6	0	662
VIDEO TRAINING	1920	39.2	42.7	0	168

Looking at the total number of interactions as given in Table 11, the pie chart in Figure 12 was generated.

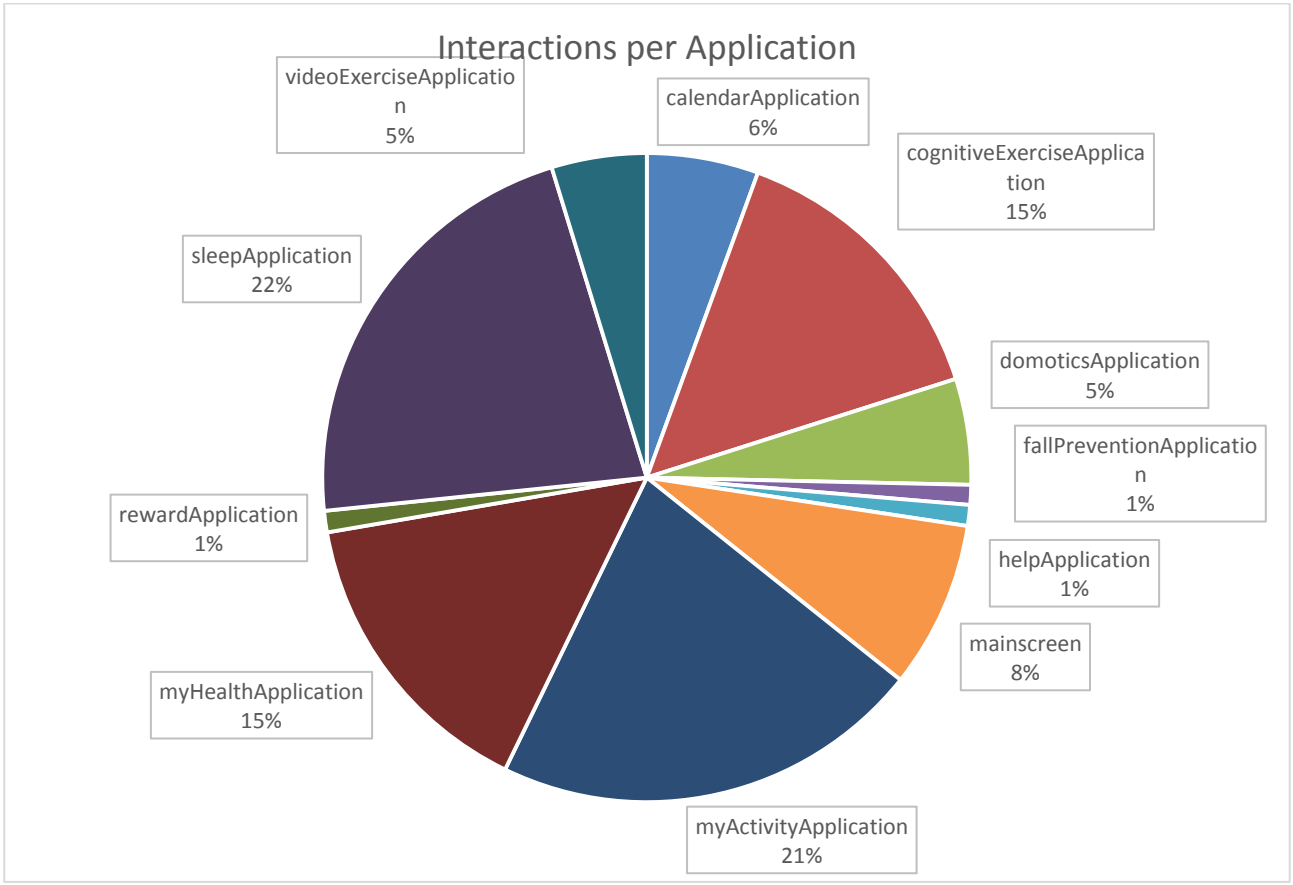


Figure 12: Distribution of total number of interactions per application for all eWALL evaluation study participants.

From these two sources, we can clearly state that there is a primary interest in the Sleep Application (22% of all interactions) and Activity Application (21% of all interactions), followed by the Health Application and Cognitive Games Application (15% of all interactions each). Over 73% of all interactions with eWALL are with these 4 applications alone. Following this, minor interest is

shown in the Calendar Application (6%), Domotics Application (5%) and Video Exercise Application (5%).

Some observations must be made regarding the domotics application and video exercise application however. The domotics application was for many people of little interest, because it was technically often difficult to get the Philips Hue (controlled through this app) to work in the user's home. Without this, there was little use of the application. For the video exercise application, looking at the total number of interactions may underestimate the value people put into this application, as it was designed specifically for minimal interaction. The application requires one tap to launch, and one tap to start a 30 minute exercise sessions, whereby all other interactions are optional.

However, for the overall data of all users, the following conclusion can be drawn:

Overall, the most popular eWALL apps are the Sleep application and Activity application, followed by the Health- and Cognitive Games applications.

From Table 11 it is clear from the reported standard deviations, minimum-, and maximum values that there is a large disparity between users. For example, for all but the Fall Prevention application, there was a user that used the application over 100 times (unfortunately including the Help application). Following this disparity, and the focus in the evaluation study on three different target groups (COPD, MCI and ARI), we look further into the specific usage of these three populations for COPD (Section 4.3.2.1), MCI (Section 4.3.2.2) and ARI (Section 4.3.2.3).

4.3.2.1 Application use for COPD

A total of 23 COPD users participated in the eWALL trial. The data for the interactions per application is reported below in Table 12.

Table 12: Total, mean, standard deviation, minimum and maximum amount of interactions per application for the 23 COPD users in the eWALL evaluation study.

FUNCTIONALITY (COPD USERS)	TOTAL INTERACTIONS	MEAN INTERACTIONS	STANDARD DEVIATION	MINIMUM INTERACTIONS	MAXIMUM INTERACTIONS
CALENDAR	985	41.0	101.2	0	483
COGNITIVE GAMES	1454	60.6	80.7	0	341
DOMOTICS	751	31.3	43.0	0	163
FALL PREVENTION	149	6.2	4.6	0	15
HELP	221	9.2	17.0	0	85
MAIN SCREEN	2019	84.1	129.5	0	661
ACTIVITY BOOK	4442	185.1	167.1	0	673
HEALTH BOOK	4091	170.5	152.4	0	584

REWARD APP	139	5.8	5.3	0	17
SLEEP BOOK	4310	179.6	143.9	0	613
VIDEO TRAINING	913	38.0	38.9	0	168

From the data in Table 12, the pie chart in Figure 13 is generated based on the total number of interactions with each application.

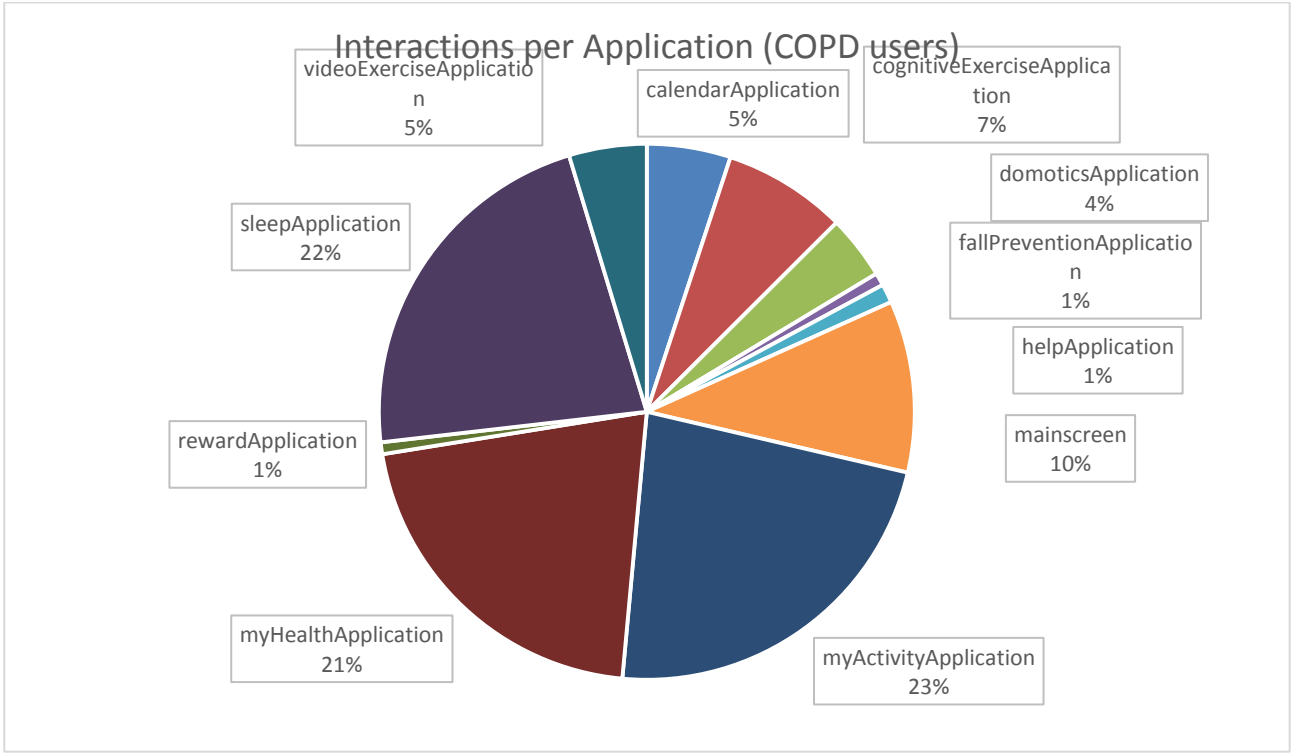


Figure 13: Distribution of total number of interactions per application for the 23 COPD eWALL evaluation study participants.

The difference in preference for applications is partly expected. Compared to the overall user data in Figure 12, there is less interest in the Cognitive Games application from the COPD user group. The most used applications for the COPD target group are the Activity Application (23%), Sleep Application (22%) and Health Application (21%). These applications were designed, mainly for the purpose of the COPD target group. The lack of use of the Video Exercise Application (5%) is remarkable, as this application was also designed for the COPD target group. However, the application was also designed with a minimum need for interaction, so the statistics may not favor this application.

!	**COPD users favor the Activity, Sleep and Health applications above all other eWALL functionalities.**

4.3.2.2 Application use for MCI

A total of 15 MCI users participated in the eWALL evaluation study. The data for this group of users is reported in Table 13. From the total number of interactions in the MCI group, the pie chart in Figure 14 was generated.

Table 13: Total, mean, standard deviation, minimum and maximum amount of interactions per application for the 15 MCI users in the eWALL evaluation study.

FUNCTIONALITY (COPD USERS)	TOTAL INTERACTIONS	MEAN INTERACTIONS	STANDARD DEVIATION	MINIMUM INTERACTIONS	MAXIMUM INTERACTIONS
CALENDAR	514	34.3	48.8	5	200
COGNITIVE GAMES	3500	233.3	200.9	31	700
DOMOTICS	391	26.1	24.3	1	75
FALL PREVENTION	172	11.5	14.0	1	46
HELP	156	10.4	24.4	0	100
MAIN SCREEN	963	64.2	58.1	4	198
ACTIVITY BOOK	2807	187.1	200.5	8	608
HEALTH BOOK	423	28.2	34.1	2	140
REWARD APP	222	14.8	26.6	0	106
SLEEP BOOK	2644	176.3	161.0	0	520
VIDEO TRAINING	421	28.1	25.2	3	98

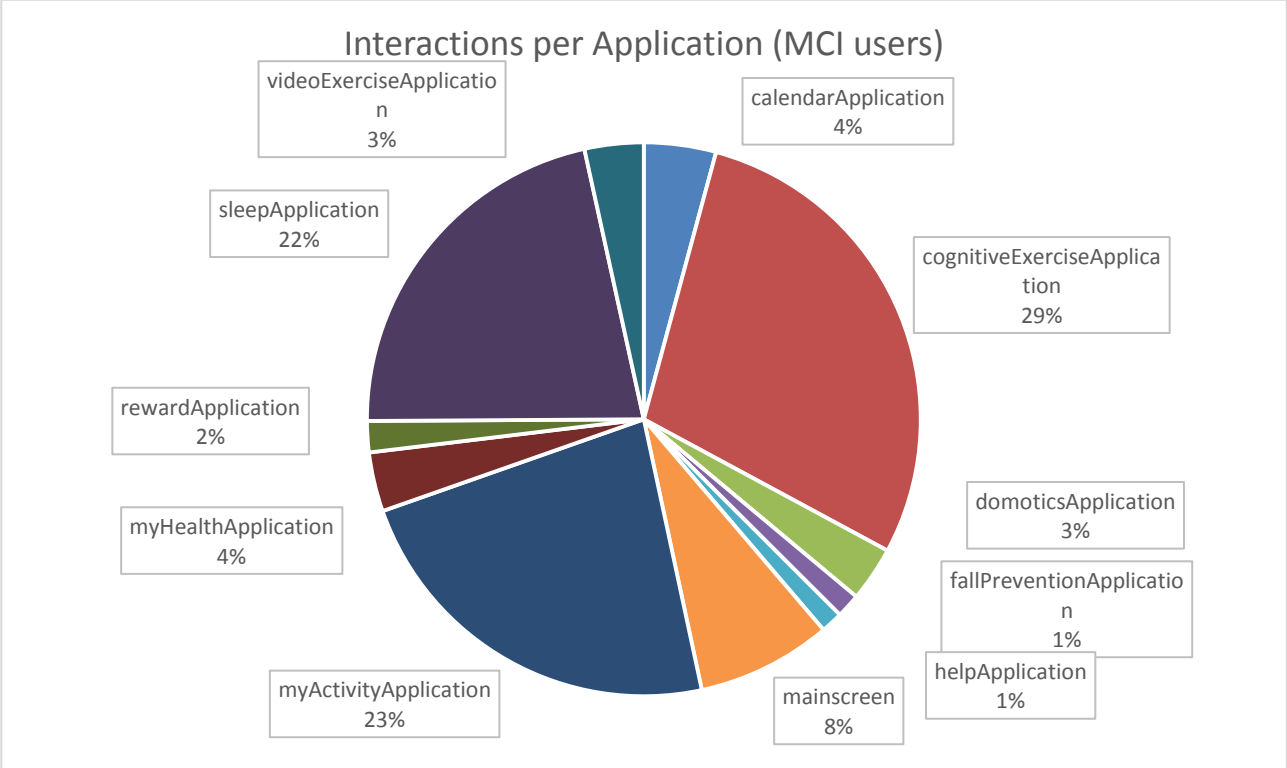


Figure 14: Distribution of total number of interactions per application for the 15 MCI eWALL evaluation study participants.

Similar to the analysis of the COPD specific data, there is an expected difference with the MCI interactions per application from the overall user data. The Cognitive Exercise Application, which was specifically designed for the MCI target population is much more popular among these users. The most popular applications for MCI users are the Cognitive Exercise Application (29%), Activity Application (23%) and Sleep Application (22%), with all other applications following with significantly less interactions.

!	**MCI users favor the Cognitive Exercise, Activity, and Sleep applications above all other eWALL functionalities.**

4.3.2.3 Application use for ARI

A total of 10 ARI users participated in the eWALL evaluation study. The interaction data per application is provided in Table 14 below. From the data in Table 14 (total number of interactions per application), the pie chart in Figure 15 was generated.

Table 14: Total, mean, standard deviation, minimum and maximum amount of interactions per application for the 10 ARI users in the eWALL evaluation study.

FUNCTIONALITY (COPD USERS)	TOTAL INTERACTIONS	MEAN INTERACTIONS	STANDARD DEVIATION	MINIMUM INTERACTIONS	MAXIMUM INTERACTIONS
CALENDAR	756	75.6	91.9	0	276
COGNITIVE GAMES	927	92.7	119.0	0	328
DOMOTICS	997	99.7	148.7	0	457
FALL PREVENTION	80	8.0	9.1	0	30
HELP	45	4.5	5.9	0	18
MAIN SCREEN	393	39.3	51.3	0	128
ACTIVITY BOOK	1455	145.5	121.8	27	359
HEALTH BOOK	1606	160.6	164.6	12	516
REWARD APP	71	7.1	10.7	0	36
SLEEP BOOK	1920	192.0	197.8	14	662
VIDEO TRAINING	586	58.6	61.6	1	160

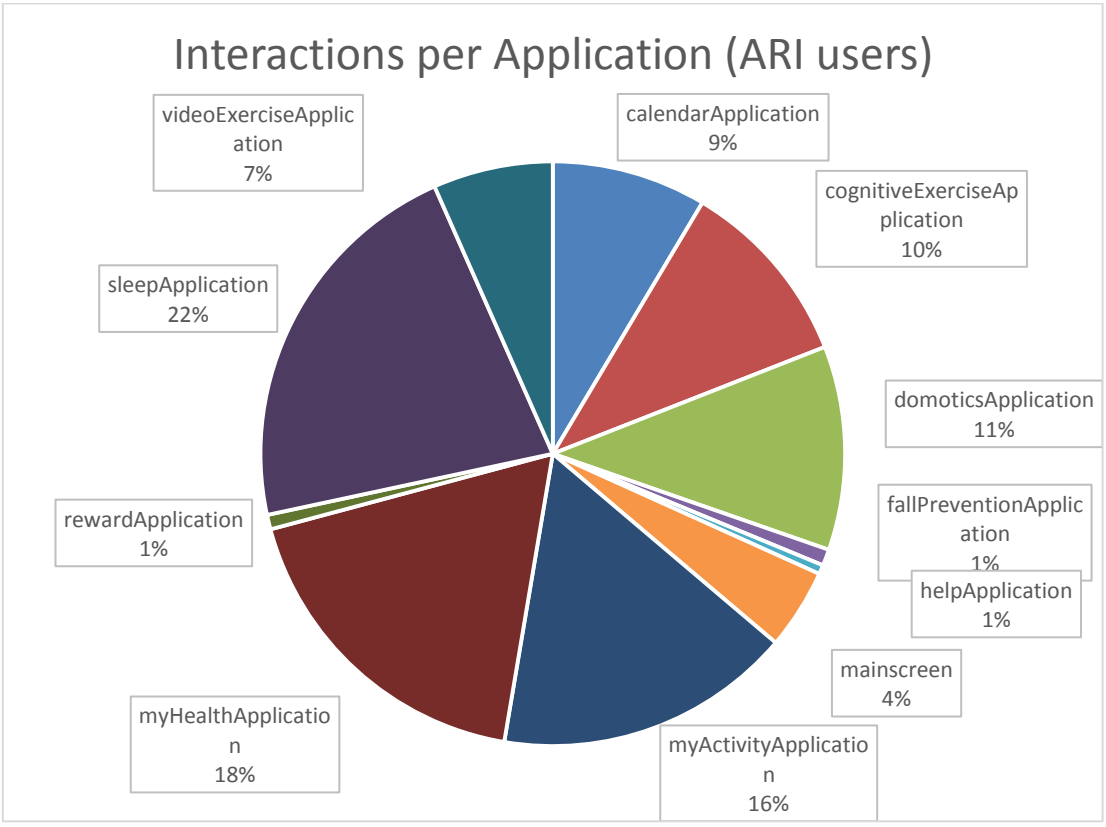


Figure 15: Distribution of total number of interactions per application for the 10 ARI eWALL evaluation study participants.

The analysis of application use for the ARI population shows again a result that matches with the design philosophy of the eWALL project. In this case, the distribution of total interactions per application is much more spread. Indeed, the ARI population can be seen as lying somewhere between COPD (focus on physical improvement functionalities), and MCI (focus on cognitive improvement functionalities). As such, the spread in application preference is expected. For MCI users, the popular applications are, similar to the COPD population: Sleep Application (22%), Health Application (18%), Activity Application (16%). For the MCI population, the "second favorite apps" follow much closer with the Domotics Application (11%), Cognitive Exercise Application (10%), Calendar Application (9%) and Video Exercise Application (7%) all receiving a significant share of attention from the users.

Although ARI users favor the Sleep, Health and Activity applications, secondary applications (Domotics, Cognitive Exercise, Calendar and Video Exercise) receive ample attention.

4.3.3 Daily application usage versus sporadic usage

This section addresses the third research question: "*Which applications are used every day, which applications are used sporadically?*" The previous section analyses in detail which applications are favorite to the eWALL users in general and to the specific target groups of COPD, MCI and ARI users. The analysis is based on the total number of measured interactions with specific applications. This analysis method may provide a skewed vision on the popularity of applications as some eWALL apps might not require or invite many interactions (by e.g. focusing on providing information at a glance). In this analysis we disregard the total number of interactions, and instead focus on which applications are used (at least once) on each day.

Table 15: Indication of the percentage of days on which a user interacted with a specific application. E.g. a value of 100% in this table, means that the user interacted with the application every day of the eWALL evaluation period.

USER	DOMOTICS	MAIN SCREEN	ACTIVITY APP	HELP APP	HEALTH APP	FALL PREVENTION	SLEEP APP	REWARD APP	VIDEO EXERCISE	COGNITIVE EXERCISE	CALENDAR APP
NL-1	24.1%	31.0%	31.0%	3.4%	34.5%	6.9%	20.7%	6.9%	10.3%	6.9%	3.4%
NL-2	3.2%	38.7%	61.3%	3.2%	32.3%	3.2%	25.8%	3.2%	9.7%	9.7%	3.2%
NL-3	19.0%	38.1%	76.2%	9.5%	85.7%	4.8%	52.4%	14.3%	23.8%	23.8%	14.3%
NL-4	16.7%	27.8%	94.4%	0.0%	44.4%	5.6%	94.4%	5.6%	11.1%	27.8%	5.6%
NL-5	38.1%	100.0%	90.5%	33.3%	90.5%	14.3%	81.0%	23.8%	71.4%	76.2%	28.6%
NL-6	13.9%	86.1%	91.7%	11.1%	80.6%	16.7%	80.6%	0.0%	25.0%	25.0%	25.0%
NL-7	7.4%	59.3%	55.6%	3.7%	29.6%	7.4%	51.9%	3.7%	18.5%	14.8%	3.7%
NL-8	55.6%	100.0%	100.0%	22.2%	100.0%	33.3%	100.0%	44.4%	11.1%	11.1%	11.1%

NL-9	8.3%	62.5%	75.0%	8.3%	58.3%	4.2%	70.8%	8.3%	41.7%	54.2%	16.7%
NL-10	0.0%	18.5%	77.8%	0.0%	85.2%	0.0%	88.9%	0.0%	11.1%	14.8%	11.1%
NL-11	14.3%	57.1%	71.4%	28.6%	71.4%	28.6%	42.9%	42.9%	42.9%	28.6%	42.9%
NL-12	0.0%	50.0%	87.5%	4.2%	54.2%	12.5%	41.7%	12.5%	29.2%	4.2%	4.2%
NL-13	10.7%	28.6%	53.6%	10.7%	28.6%	7.1%	46.4%	21.4%	10.7%	21.4%	3.6%
NL-14	27.6%	72.4%	65.5%	10.3%	69.0%	10.3%	79.3%	3.4%	24.1%	69.0%	24.1%
NL-15	48.4%	74.2%	100.0%	32.3%	100.0%	12.9%	87.1%	16.1%	29.0%	41.9%	38.7%
NL-16	11.1%	55.6%	66.7%	22.2%	55.6%	33.3%	44.4%	11.1%	22.2%	55.6%	55.6%
NL-17	5.4%	35.1%	37.8%	5.4%	37.8%	5.4%	18.9%	5.4%	8.1%	24.3%	5.4%
NL-18	34.3%	100%	94.3%	11.4%	48.6%	14.3%	68.6%	14.3%	25.7%	40.0%	97.1%
NL-19	26.3%	100%	97.4%	55.3%	97.4%	5.3%	94.7%	13.2%	31.6%	13.2%	2.6%
NL-20	7.1%	85.7%	50.0%	14.3%	78.6%	14.3%	78.6%	7.1%	28.6%	14.3%	21.4%
NL-21	0.0%	80.0%	66.7%	0.0%	66.7%	0.0%	66.7%	0.0%	6.7%	6.7%	13.3%
AT-1	76.9%	38.5%	84.6%	0.0%	61.5%	0.0%	53.8%	0.0%	46.2%	61.5%	61.5%
AT-2	93.1%	89.7%	96.6%	17.2%	100%	34.5%	96.6%	17.2%	48.3%	79.3%	51.7%
AT-3	24.1%	75.9%	72.4%	20.7%	51.7%	10.3%	48.3%	6.9%	62.1%	31.0%	13.8%
AT-4	96.4%	89.3%	100.0%	7.1%	100%	17.9%	96.4%	21.4%	57.1%	82.1%	92.9%
AT-5	12.5%	20.8%	37.5%	0.0%	16.7%	8.3%	33.3%	8.3%	25.0%	4.2%	4.2%
DK-1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
DK-2	0.0%	25.0%	75.0%	0.0%	75.0%	12.5%	12.5%	12.5%	25.0%	25.0%	12.5%
DK-3	0.0%	0.0%	42.9%	0.0%	42.9%	0.0%	14.3%	0.0%	14.3%	14.3%	0.0%
DK-4	7.1%	7.1%	57.1%	0.0%	64.3%	0.0%	28.6%	0.0%	7.1%	0.0%	0.0%
DK-5	7.7%	30.8%	53.8%	15.4%	61.5%	30.8%	23.1%	23.1%	30.8%	23.1%	30.8%
DK-6	0.0%	0.0%	50.0%	0.0%	50.0%	0.0%	40.9%	4.5%	4.5%	4.5%	0.0%
DK-7	6.7%	0.0%	66.7%	13.3%	86.7%	13.3%	86.7%	13.3%	26.7%	20.0%	26.7%
DK-8	0.0%	7.1%	42.9%	7.1%	71.4%	14.3%	42.9%	7.1%	21.4%	21.4%	21.4%
IT-1	21.1%	44.7%	63.2%	7.9%	21.1%	13.2%	50.0%	31.6%	13.2%	55.3%	18.4%
IT-2	11.5%	96.2%	96.2%	26.9%	50.0%	19.2%	88.5%	3.8%	30.8%	80.8%	65.4%
IT-3	5.6%	55.6%	77.8%	11.1%	25.0%	19.4%	63.9%	8.3%	19.4%	69.4%	11.1%
IT-4	2.2%	17.4%	15.2%	0.0%	2.2%	6.5%	4.3%	4.3%	6.5%	6.5%	4.3%
IT-5	2.8%	36.1%	27.8%	0.0%	19.4%	2.8%	13.9%	5.6%	19.4%	16.7%	2.8%
IT-6	2.0%	14.0%	18.0%	2.0%	10.0%	2.0%	20.0%	0.0%	6.0%	14.0%	2.0%
IT-7	3.6%	42.9%	46.4%	7.1%	28.6%	3.6%	35.7%	7.1%	21.4%	46.4%	3.6%
IT-8	5.9%	35.3%	26.5%	2.9%	11.8%	5.9%	14.7%	8.8%	5.9%	11.8%	5.9%
IT-9	8.7%	69.6%	34.8%	13.0%	17.4%	13.0%	21.7%	21.7%	39.1%	91.3%	30.4%
IT-10	0.0%	27.3%	13.6%	0.0%	4.5%	4.5%	0.0%	0.0%	4.5%	31.8%	9.1%
IT-11	11.1%	18.5%	33.3%	7.4%	25.9%	11.1%	25.9%	7.4%	18.5%	22.2%	3.7%
IT-12	21.7%	73.9%	91.3%	69.6%	87.0%	52.2%	91.3%	47.8%	21.7%	78.3%	52.2%
IT-13	11.8%	35.3%	64.7%	5.9%	11.8%	17.6%	70.6%	11.8%	35.3%	64.7%	23.5%
IT-14	6.7%	53.3%	20.0%	13.3%	20.0%	6.7%	13.3%	6.7%	6.7%	46.7%	26.7%
IT-15	4.2%	16.7%	20.8%	4.2%	4.2%	4.2%	20.8%	4.2%	4.2%	12.5%	4.2%
TOTALS:	**17.1%**	**55.0%**	**73.7%**	**10.6%**	**61.7%**	**11.1%**	**62.6%**	**13.6%**	**24.3%**	**27.7%**	**14.1%**

From Table 15, we can generate a ranking of which applications are used on most days during the eWALL evaluation. This ranking is as follows:

1. My Activity Application (73.7% daily use)
2. Sleep Application (62.6% daily use)
3. Health Application (61.7% daily use)
4. Main Screen (55.0% daily use)
5. Cognitive Exercise Application (27.7% daily use)
6. Video Exercise Application (24.3% daily use)
7. Domotics Application (17.1% daily use)
8. Calendar Application (14.1% daily use)
9. Reward Application (13.6% daily use)
10. Fall Prevention Application (11.1% daily use)
11. Help Application (10.6% daily use)

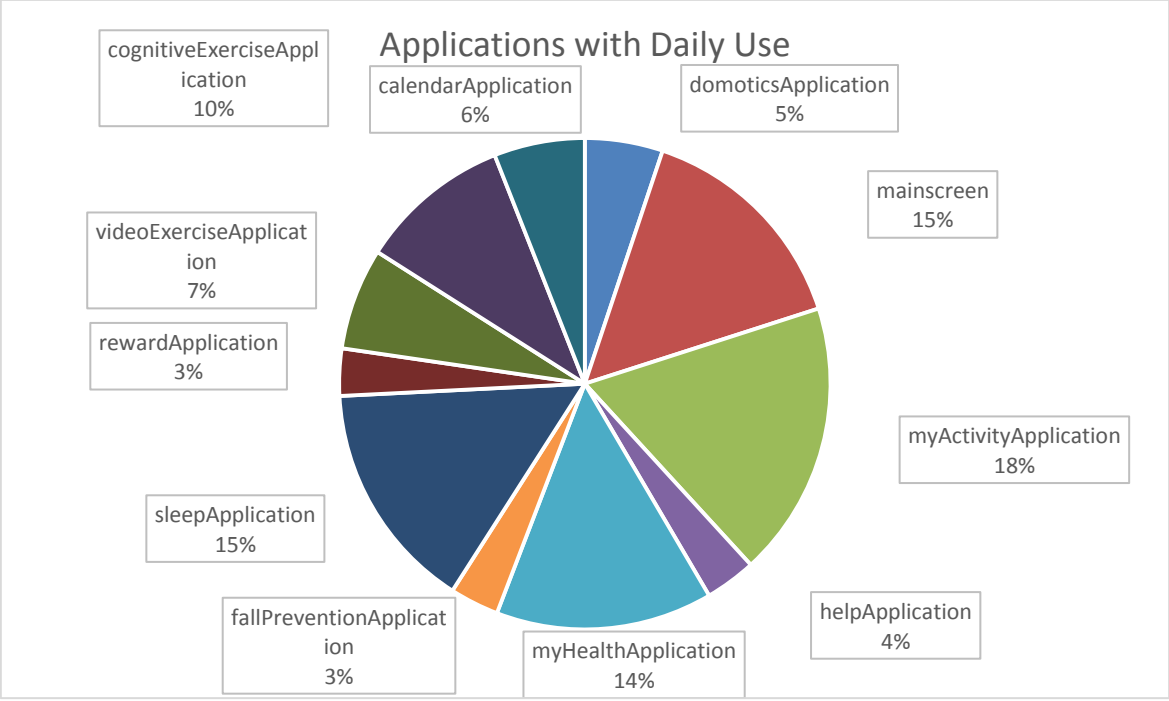


Figure 16: Distribution of daily used applications for all eWALL users.

In Figure 16 the total values of Table 15 are plotted in a pie chart, showing a very similar distribution pattern compared to the analysis performed in Section 4.3.2.

The question of which applications are used daily is answered as follows:

!	**The <u>Activity</u>, <u>Sleep</u> and <u>Health</u> applications are used at least every other day on average by all eWALL users. The <u>Cognitive Exercise</u> and <u>Video Exercise</u> application are used at least every week.**

4.3.4 eWALL usage over the day

We would like to know whether the eWALL is primarily used e.g. in the mornings, evenings or afternoons. A detailed analysis on the timestamps of the interaction log events was performed. Figure 17 below shows a histogram of eWALL use for all eWALL users in the evaluation. The data was divided into 96 bins (15 minute slots), and plotted from midnight to midnight.

The analysis shows that eWALL interactions occur evenly over the day, picking up between 07:00 and 08:00 in the morning and showing a stable number of interactions until 19:00 in the evening. The evening period between 19:00 and 00:00 shows a slightly lower, but again stable use.

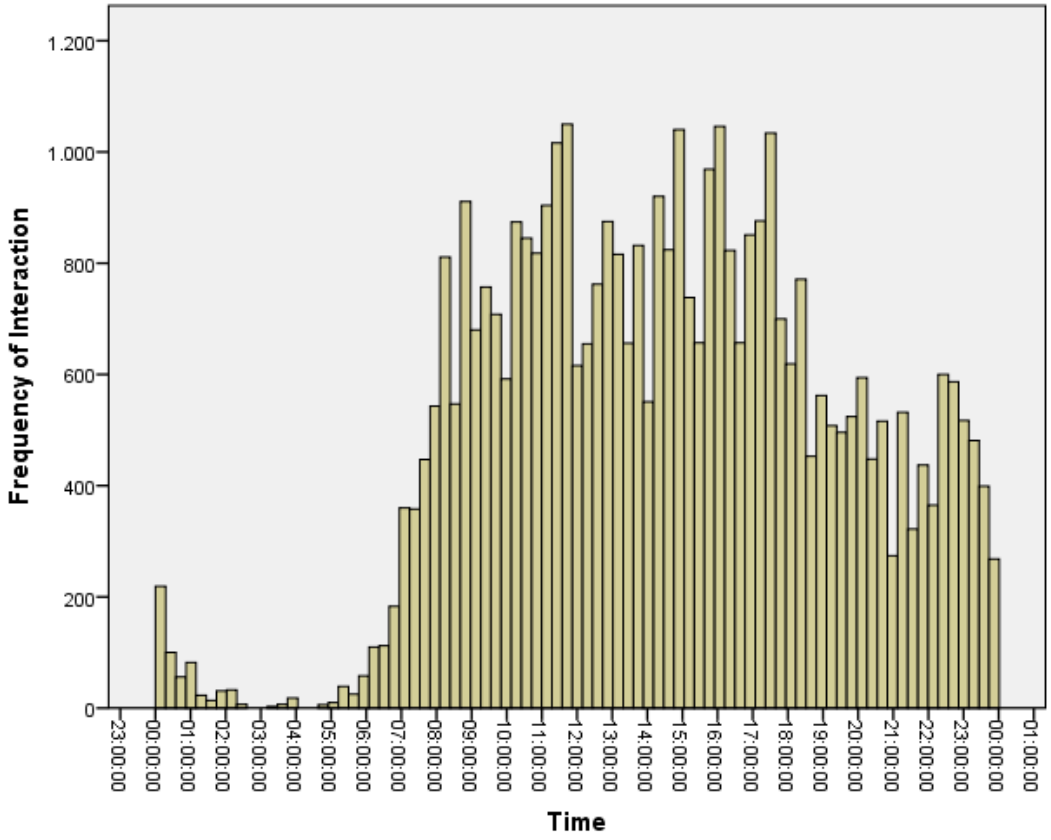


Figure 17: Histogram of eWALL use over the day for all eWALL users.

!	**The eWALL is a part of everyday life and is used throughout the waking hours of the day in a stable pattern (on average for all eWALL users).**

4.4 Potential Clinical Effects

In this section we start by analyzing the SF-36 and iADL data that was obtained in all countries, except for Denmark. The most important question is to see whether there are any differences in individual patients before- and after the eWALL evaluation. The results below are sub-divided into MCI, COPD (excluding the Danish COPD users), and ARI (excluding the Danish ARI users). It is not possible to compare all three target groups, as there were differences in the language specific

versions of the SF-36 and iADL questionnaires. For example, in the Netherlands, iADL scores range between 0-24 where lower scores indicate a higher patient ability, whereas in Italy and Austria the score ranges from 0-8 whereby lower scores mean a higher patient ability.

4.4.1 General effects (SF-36, iADL)

MCI

Table 16 shows the results of the SF-36 and the iADL performed in Italy on MCI subjects. Differences between the pre-test and post-test were analyzed using the paired t-test, but no significant differences were found.

Table 16: Results of general effects (SF-36 and iALD), MCI; n=15

Measurement instrument	Pre-test (mean±SD)	Post-test (mean±SD)
Subjectively perceived quality of life		
SF-36		
- Physical functioning	69.67(±5.03)	70.00(±4.34)
- Social functioning	67.27(±4.00)	66.47(±4.15)
- Role limitations (physical)	58.33(±9.34)	58.33(±8.33)
- Role limitations (emotional)	46.27(±7.09)	44.00(±6.17)
- Pain	73.40(±4.13)	74.47(±4.09)
- General health perception	46.73(±3.98)	46.07(±4.06)
- Vitality	51.33(±2.82)	51.00(±1.56)
- Mental health	66.93(±2.88)	64.27(±2.39)
Subjectively perceived independent living		
iADL	7.13(±1.13)	7.13(±1.13)

COPD

Table 17 shows the results of the SF-36 and the iADL performed in The Netherlands on COPD subjects. Paired t-tests were used to analyze differences between pre-test and post-test, but no significant differences were found.

Table 17: Results general effects for COPD in The Netherlands; n=21

Measurement instrument	Pre-test (mean±SD)	Post-test (mean±SD)
Subjectively perceived quality of life		
SF-36		
- Physical functioning	18.52(±5.49)	19.00(±4.82)
- Social functioning	7.52(±1.89)	7.88(±1.67)
- Role limitations (physical)	5.38(±1.72)	5.65(±1.54)
- Role limitations (emotional)	5.00(±1.22)	5.41(±1.18)
- Mental health	25.19(±3.94)	26.06(±3.23)
- Vitality	15.29(±4.20)	15.94(±2.73)
- Pain	49.43(±15.00)	47.82(±14.91)
- General health perception	12.76(±3.28)	12.06(±3.90)
- Health change	2.71(±1.01)	2.71(±1.05)
Subjectively perceived independent living		
iADL	2.81(±4.35)	2.29(±2.39)

ARI

Table 18 shows the results of the SF-36 for ARI subjects participating in Austria. Differences between the pre-test and post-test were analyzed using the paired t-test, but no significant differences were found. Considering the iADL, all participants had a maximum score of 8 points on the pre-test.

Table 18: Results general effects for ARI in Austria; n=5

Measurement instrument	Pre-test (mean±SD)	Post-test (mean±SD)
Subjectively perceived quality of life		
SF-36		
- Physical functioning	25.20(±3.49)	24.00(±5.00)
- Social functioning	9.40(±1.34)	9.20(±1.30)
- Role limitations (physical)	7.40(±1.34)	6.20(±2.05)
- Role limitations (emotional)	5.40(±1.34)	5.60(±0.89)
- Mental health	22.00(±2.55)	22.40(±1.67)
- Vitality	16.60(±2.70)	16.20(±2.86)
- Pain	48.80(±4.15)	44.00(±10.63)
- General health perception	18.80(±2.70)	19.80(±2.95)
- Health change	3.00(±1.22)	3.20(±1.10)

4.4.2 Specific effects

4.4.2.1 MCI

When considering the short intervention period (from 2 to 6 weeks), it was clearly stated (D8.1) that the primary outcome of the study would be the acceptance of the system rather that improvements in the evolution of the cognitive conditions. Indeed, is was quite unlikely that significant modulations of the cognitive status would be observed in so a short period. MMSE and Neuropsychological battery tests were administered at the beginning and at the end of the intervention test. As expected, there were no differences between pre-test and post-test.

4.4.2.2 COPD

Considering the physical capacity, 26.3% scored frail on the Timed-Up-and-Go Test during the pre-test. During the post-test, 26.7% of the participants scored frail. Table 19 shows the results of the CCQ and the 6-Minutes Walking Test. The paired t-test showed there were no differences between pre-test and post-test.

Table 19: Results of CCQ and 6-Minutes Walking Test for the Dutch COPD users (n=21).

Measurement instrument	Pre-test (mean±SD)	Post-test (mean±SD)
General health status at group level		
CCQ		
- Symptom status	3.32(±1.32)	3.12(±1.18)
- Functional status	2.15(±1.00)	1.90(±1.10)
- Mental status	1.26(±1.21)	1.26(±1.20)
- Total Score	2.44(±0.91)	2.56(±0.87)
Physical capacity		

6MWT	360.06(±115.33)	372.21(±103.58)

5 Conclusions

The eWALL evaluation study was concluded with a total of 48 subjects, divided over three user groups and in four different evaluation sites. In Italy, 15 MCI users were included; in the Netherlands 21 COPD users, in Denmark 2 COPD and 5 ARI users and in Austria 5 ARI users. Due to some technical complexities that could not be solved on time for all participants, some users did not finish the full planned evaluation period. On average, users were using eWALL for 24 days.

One of the quanitfiable success indicators of the project as indiciated in the DOW is the desire to produce an integrated solution that can be deployed in less than a day. The integrated solution built around the cabinet in the Netherlands (see Section 3.2.1) clearly checks the mark with a solution that was deployed in many homes in less than 30 minutes.

An analysis of the acceptance of the technology after using eWALL showed an overall positive result over all three user groups, with no significant differences between the groups. Especially the "aesthetic", "control", and "ease of use" of the system scored high in the analysis. An additional analysis using the traditional User Experience Questionnaire in Austria, furthermore showed that eWALL scored excellent on "perspicuity", meaning that the system is intelligible and easy to learn, as well as high on "attractiveness".

All interactions with the eWALL service were logged for later analysis by the eWALL researchers. Although the logging service contained a number of issues, the results obtained from this data were very valuable. From the log data it was clearly visible that eWALL users were using the eWALL on a daily basis, with over 30 interactions on average per day. In the initial week of using eWALL, use was even higher, although this can be attributed to a novelty effect. Besides overall eWALL use, a careful analysis was performed on the popularity of the individual applications. Overall, the most popular eWALL apps are the Sleep Application and Activity Application, followed by the Health Application and Cognitive Games. Between the different users groups there were expected differences in application popularity, with e.g. MCI users preferring the Cognitive Games above all else, and the ARI group showing a more diversified interest in the applications. The Activity Application, Sleep Application, and Health Application were overall clear eWALL favorites. These applications were used at least every other day on average by all eWALL users. When looking at the eWALL usage over the course of a day it becomes clear that the eWALL is a part of everyday life and is used throughout the waking hours of the day in a stable pattern.

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UEQ http://www.ueq-online.org/

7 Abbreviations

6MWT	Six-Minute Walking Test
ADL	Activity of Daily Living
ARI	Age Related Impairment
CCQ	Clinical COPD Questionnaire
COPD	Chronic Obstructive Pulmonary Disease
DoW	Description of Work
DSM	Diagnostic and Statistical Manual of Mental Disorders
EC	Ethics Committee
eWALL	electronic Wall for Active Long Living
GOLD	Global initiative for chronic Obstructive Lung Disease
GUI	Graphical User Interface
ICT	Information and Communication Technology
MCI	Mild Cognitive Impairment
MMSE	Mini-Mental State Examination
QoL	Quality of Life
SE	Standard Error
SF36	Short Form health survey
TAM	Technology Acceptance Model
UEQ	User Experience Questionnaire
WP	Work Package

8 Appendix A - Lab Evaluations of new eWALL functionalities

8.1 Introduction

The main interface between the final users and the eWALL platform is provided by applications. The eWALL applications are web-based, meaning that they are designed to be executed and rendered in a web browser, and to deploy functionalities described and designed to address and overcome users' needs. A further design phase was developped during the last part of the project to propose new and challenging functionalities to be ready for eWALL 2.0 release at the end of the actual project. Due to this, a new important task was to design new functionalities in a way that provides good quality of service and user-friendly interfaces.

Demonstration partners, namely RRD, ATE, AAU, and IRCCS, agreed to build focus groups of experts or users toevaluate new functionalities. Discussions and comments on each functionality will be used to drive technical and implementative choices with the aim ofimproving efficacy of proposed new applications and maximize the focus on real users' needs.

8.2 New functionalities

During the development of the eWALL system, several functionalities were designed to be implemented in applications; some of them, despite focusing and addressing properly user needs., were not deployed in the final platform and were not evaluated in a home environment. However, it was decided to evaluate these new functionalities in a laboratory environment. A collection of new and promising functionalities are described in the following sections.

8.2.1 My Settings Application

The application allows users to manipulate their own settings for experiencing a more satisfying degree of personalization and increased feelings of control that allows for a higher degree of privacy. Providing end-users with the right options with respect to storing and sharing personal (health) data, enables the technology to comply with European privacy legislation. Finally, it also allows the user to correct eventual errors of automatic setup.

The primary user is able to change settings in his/her user profile:

- his/her user data
- preferences in notification types
- preferences for wellbeing advertisements
- settings for widgets (e.g. select different clock styles)

The MySettings application starts by pressing the MySettings icon from the main screen. The MySettings icon is located top right on the main screen next to the clock. When the app is opened, it is shown an overview where the user can select ‘Sharing data with others’, ‘My Notifications’, and ‘My eWALL appearance’ (Figure 18).

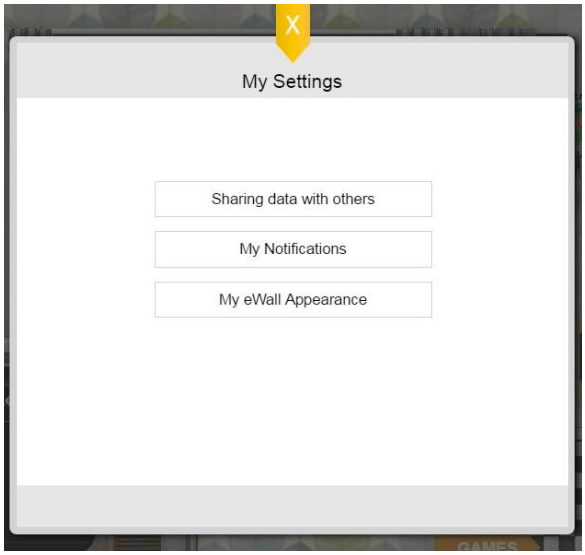


Figure 18"My Settings" Application

If the user selects 'Sharing data with others', he will have to select one from these categories: 'Nobody', 'Everybody' and 'Let me decide'. When the user clicks on 'Let me decide', he will have the choice to give an access to his personal information to selected caregivers and family people.

When the user visits the 'Notifications' option, he/she can set which types of notifications he/she does and does not want to receive, and how often. Under every topic (health advice, house information and medical signs) the user sees the options 'Never', 'Only when something is wrong', and 'Keep me updated constantly'.

The "My eWALL Appearance" menu gives the user possibility to arrange his main screen. He/She has the choice to select from three different wallpapers. He/She can also select which books and games wants to be shown on his main screen. Family picture and eWALL photos are the selections for the photo frame.

8.2.2 Hue light control

The Hue application allows the end user to control the Philips Hue system in the home, which is a commercial kit providing a control hub and a set of wireless led bulbs (the kit selected in the bill of material contains 3 bulbs) which can be set to any colors programmatically. When the main screen is launched, a check is performed on the presence of a Philips Hue hub in the home (via a network device discovery mechanism). Since the hub is wireless, a mechanism for granting control only to authorized people living in the home is required.

If the Hue application is properly configured in the Portal for a specific user, a lamp is shown in the mainscreen on the shelf, in the bottom right side (Figure 19).

Figure 19: The lamp as a metaphor for the Hue light control application

When pressing on the lamp, the control interface shows up, allowing to control the bulbs. By clicking one of the lamps on the interface, colored circles appear together with a slider and a switch on/off button. Pressing one of the circles turns the lamp on and set the bulb color to the circle color (Figure 20). Changing the slider position the light intensity can be tuned.

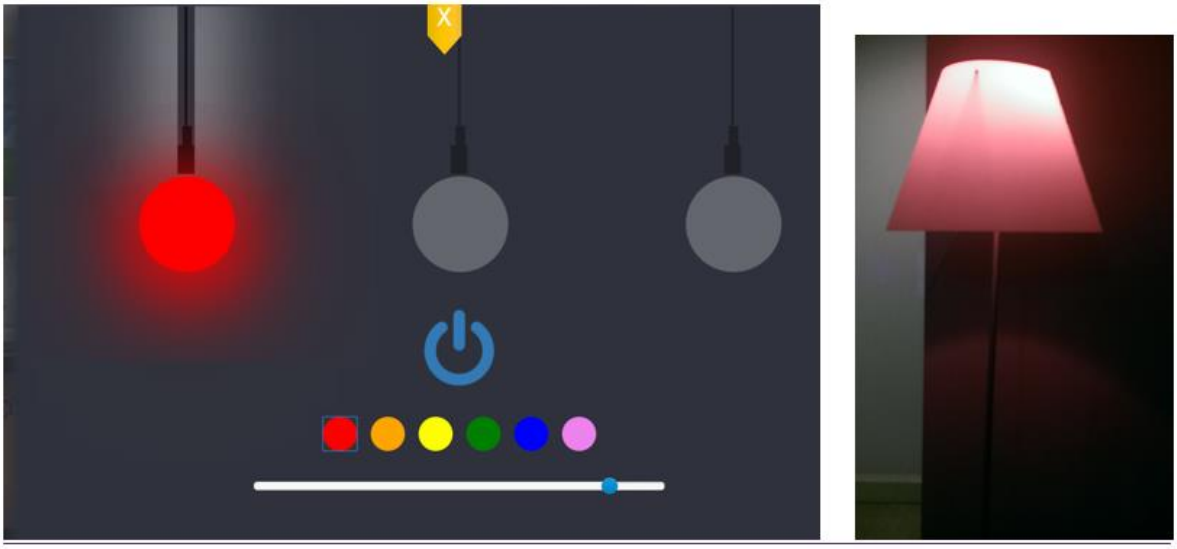


Figure 20: Hue application control (red) and effect on real lamp

8.2.3 MyKitchenManager Application

MyKitchenManager is an application for managing the ingredients the user has in the fridge or pantry, planning what needs to be bought and exploring recipes. It is launched from the eWALL main screen using an icon on the top of the shelves. The user is welcomed by an overview screen

that gives a brief overview of the functionality and allows access to the five screens of the application(cf. Figure 21):

- Overview,
- Fridge management,
- Pantry management,
- Recipes browse and search, and
- Shopping list management

Figure 21: MyKichenmanager overview screen

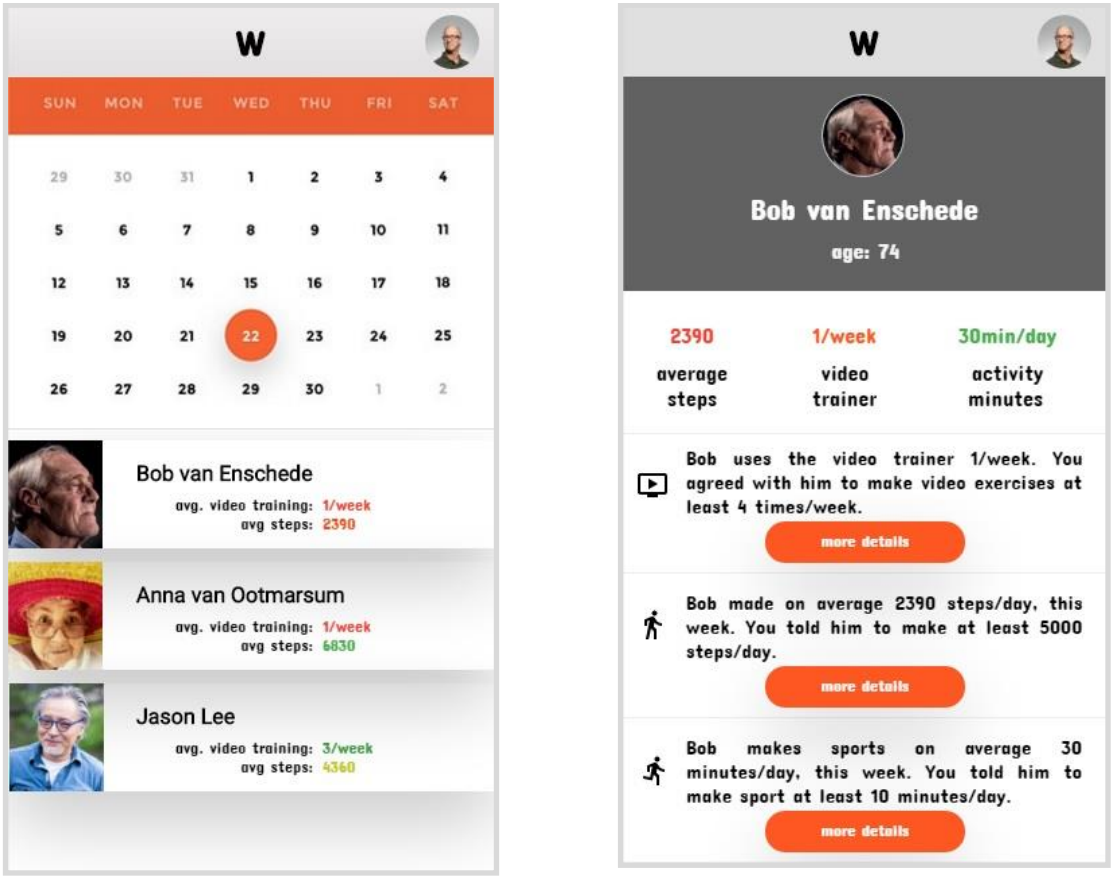
Upon selecting the fridge, the user can see its contents or browse through ingredients to add. The pantry screen works the same way, only different aisles are shown. The shopping list screen is also similar. Finally, the Recipes screen allows browsing the available recipes or searching for them based on any number of ingredients. Recipes are presented with an image, a list of ingredients and some instructions text. The ingredients on the list are colored blue if they are to be found in the fridge, green if they are to be found in the pantry, and orange if they are added to the shopping list. Clicking on any ingredient adds it to the shopping list.

Recipes can also be searched based on any number of ingredients from all aisles. The matching recipes are sorted by the number of query ingredients they require.

8.2.4 Video Trainer Companion Application

In order to provide detailed insights in the physiotherapeutic exercises performed by the patients using eWALL, a prototype smartphone application has been developed to serve as an eWALL companion app. The application is to be used by physiotherapist during, or before the consult with the patient. The eWALL smartphone application, called **W,** will allow the physiotherapist to inform himself fast and easy about his patient's status regarding adherence to his guidance and to the

eWALL physical exercises coaching. After logging in, the physiotherapist can see the calendar, with today's date selected (cf. Figure 22(a)). Below the calendar, he sees a list of eWALL users scheduled for consultations. The list contains minimum indications of the eWALL Video Trainer user's performance within the last 3 months. The color scheme indicates, as in the eWALL activity app, green for good behavior, red for bad behavior.



(a) (b)

Figure 22 (a) Screenshot of the 'W' app: Calendar overview; (b) Screenshot of the 'W' app: Patient overview.

When selecting a patient, the W app will transition to the patient's overview screen (cf. Figure 22 (b)). The therapist will see a summary of his patient's physical activity, usage of PVCS and his activity sensor. Each summary is the size of an SMS for easy reading and fast understanding. More details about the video trainer means seeing an average distribution of the PVCS usage over the past 3 months and the last week usage of the PVCS. The app summarizes the user ratings.

The therapist can see the most difficult video or the most enjoyed for the patient, as the patient rated it in the past 3 months. The application page contains the video player standard UI, as well as a summary of the ratings for this video.

8.3 Lab test Evaluations

Three groups of expert (in The Netherlands, Italy and in Denmark) and a group of users (in Austria) were asked to evaluate the new functionalities or using the eWALL system or using proper presentation and descriptions. The participants were asked to think aloud during the exploration of new functionalities and their impressions were reported as follows.

8.3.1 The Netherlands – expert evaluations

My Kitchen Manager

- It's in general unclear what the purpose of the application is.
- The instruction texts are too long and unclear.
- There is no "back" button to navigate the application easily.
- Instead of a general "explanation" page that explains all the separate functionalities, it would be better to add short explanations to each of the function's pages.
- On the explanation page it looks strange that the same icons are show twice, next to each other.
- The usage of colors for selecting / deselecting products is not clear.
- It's unclear how the "My Recipes" section works, and unclear what the different colors mean.
- The shopping list should have an integration with a mobile application, otherwise it has no use.

Lightening Settings

- It's not clear which of the light bulbs in the interface are connected to which physical lamp.
- The responsiveness is very well perceived.
- Once a lightbulb has been selected in the User Interface it's not possible to "deselect" it (the only way to remove the color / switch options is to restart the application).
- The brightness / luminosity slider did not work in the test setup (it was displayed as a text field instead of the intended slider).
- The brightness / luminosity slider should have an indication of its purpose (now you need to experiment before finding out what it does).
- Overall the responses to the application were positive.

Robot Notifications

- A general remark was made that the "off" button (for dimming the eWALL light) should not be visible while interacting with the robot.
- The activity notifications are fun, but should be adapted to the location of the user.
- Some of the activity notifications seem a bit harsh.
- The "daily goal for this week" activity message is too long, and lacks structure.
- The sleep and environment notifications seemed interesting and fun.

My Settings

- The logo clearly indicates the purpose of the application.

Sharing Settings:

- The information for sharing data with other is useful and clear.
- It is unclear which information will be shared with the settings. It would be better to split the sharing settings into separate items for each of the indicated types of data (e.g. activity, sleep …).
- It's not clear what the difference is between "physical activity" and "physical exercise" in the sharing settings.
- It would be better if there was no "Save" button, but instead an automatic saving feature.
- It's unclear that the orange highlight means that an option is selected.
- A "back" button is missing.

Notification Settings:

- These settings are considered useful by all test participants.
- The screens contain too much text. The questions themselves are clear, but they should have a better, more organized layout.
- It would be better to split the notification settings of smoke and oxygen into two separate settings.
- The word "like…" should not be used. All notification settings should be mentioned, not just examples.

Appearance Settings:

- In general also considered to be useful.
- It's not clear which of the books and games are enabled, and which are disabled.
- It would be nice to be able to enable/disable the individual games of the game board.

Video Trainer Companion Application

- It's unclear what the colors mean (average video training, average steps).
- An overview page of all clients is missing.
- A search function for clients is missing.
- Some bugs were identified in the app, e.g. images of users were not loading correctly.
- At the "more details" page
    - It's not clear what the maximum number of star rating is.
    - It's not clear what the grey and green bars mean.
    - When the video is playing, the video should be paused when pressing the centre of the screen.

8.3.2 Italy – expert evaluations

My Kitchen Manager

- First screen: There is too much text, it makes difficult to understand the purpose of the app and it can result frustrating, especially for MCI. It can be simplified, deleting some small icon and merging similar descriptions.
- The idea is pretty good, and it can help but also stimulate cognition in elderly people or with cognitive impairment.
- It could be useful to have a schematic and not full textual explanation for recipes. For example, the recipe could be subdivided in steps and images.
- The "back" button is missing.
- It is not clear how to use the shopping list app. Maybe a smart phone is needed.

Lightening Settings

A normal control is not so useful for elderly or patients with specific disease. Maybe, such application should be integrated with domotics for address special needs, i.e. turn up a soft light during the night for safety purpose (indicating the pathway to the bathroom or the kitchen).
Overall, the application is clear, not its aim.

Robot Notifications

When notifications are available, Robin the robot should change more his appearance, (just) for example he should beep when participant is in front of the screen or walk up and down on the TV cabinet.

Notifications and rewarding messages are nice and enjoyable, even more if records would be personalized with respect to the country of the user.

My Settings

My Setting application is, of course, really useful both to personalize the aspect of the system, both to set the level of privacy of the user. In "Sharing data with others" section should be useful and simple to have some more template profile, i.e. "maximum level of privacy: only me"; "medium level of privacy: me and the principal caregiver"; "low level of privacy: me, the caregivers, the GP"; "No privacy: Open data".

The possibility to change appearance makes the platform more pleasant, the opportunity to change pictures is a good way stimulate continuously subjects with cognitive impairment.

Video Trainer Companion Application

The interface is not totally clear, maybe it is better to have a web portal. Nevertheless, the functionality can be useful to understand the adherence with physic therapy of patients and it can be integrated with clinical records.

8.3.3 Denmark – expert evaluation

My Kitchen Manager

First screen (the overview):

- The experts found the content of the app understandable after they spend some time reading the text
- The high level of information is confusing
- Strange that the icons are visible in two places at the same time
- The difference between fridge and pastry is unclear

Fridge and pastry:

- Preferable if the user could find all food in the same place (no division into fridge and pastry) That would potentially spare some confusion and make the functionality easier to use as the user would have to enter less different places

My recipes:

- The meaning of the colors used in the recipes are confusing and unclear
- Annoying that the “next” button moves when you leaf through the recipes

Shopping list:

- The shopping list is easy to empty
- Positive that you can add content to the shopping list directly from the recipe
- The user should have the option of putting everything missing for a particular recipe on the shopping list by clicking just one place

General comments:

- Moving into the app itself from the “front page” one expert noticed that a “back” button was missing
- Positive that you can change between the icons in the left side of the screen
- The app is not always intuitively clear
- The use of colors is confusing
- Overall, the app is easy to use

Suggestions for improvement:

- An “empty fridge” button could be added so that the app would suggest recipes based on the entire content of the fridge – not just one ingredient
- The use of colors should be consistent and less colors should be used

- The app should guide the user more when he/she has clicked something. This could be done by adding information on both what you can do and what you just did (for instance – where did the ingredient go?)

Settings

General comments:

- The icon for the app does not relate to the content of the app
- The layout of this app is remarkably different from the other eWALL apps and one expert would like that to be standardized. However, another expert liked that the layout of this particular app differed as the content differ as well
- Less text and more icons would be preferable

Sharing data with others:

- The content is understandable. One expert found the layout boring but found that to be OK because of the use of the app
- Positive if you could choose which information to share with which other party. You could imagine that a user would only like to share some of their data with relatives or health care professionals

My notifications:

- The content is understandable
- One expert would have liked that the robot was illustrated here.
- One expert was puzzled by the use of the word constantly. What would that mean? The other expert was skeptical that the user could choose "never" due to safety reasons.

My eWALL appearance:

- The content is understandable
- Too much text
- The option of choosing books is not intuitive

8.3.4 Austria – user evaluations

After the end of the Field Trials we presented to five ARI participants additional features of eWALL and asked them for their feedback. Similar to the Small Scale Evaluations, a task-based approach was used, meaning that we gave them some tasks to fulfill in the new eWALL functionalities. Furthermore, the participants were asked to think aloud during the tasks.

My Kitchen Manager

After opening the My Kitchen Manager application, we asked the participants to tell us what they think the application provides to the user. In general, the aim of the application was clear to the

participants. One participant thought that eWALL automatically recognizes the groceries in the fridge and orders new groceries if they get empty.

By trying out the system, the following problems/recommendations for change came up:

- My Kitchen Manager Overview:
  - Delete the smaller images of the fridge etc. as participants taped on those instead of the bigger ones on the left.
- My Recipes:
  - Enlarge the "Next" button in the bottom.
  - Participants didn't recognize that the groceries shaded in blue are those that are already in the fridge.
  - One participant would use drag & drop to put the groceries on the shopping list instead of taping on it. And instead of "select for fridge" he would also use drag & drop to put the groceries in the fridge.

After trying out the system, two participants indicated they would use the recipes provided by eWALL. One participant also searches for recipes in the intranet and found it nice to look for new recipes on eWALL to prepare the meal for next day. Another participant brought up the idea that eWALL should recommend a recipe based on the available groceries in the fridge and in the pantry. In this case, he said, the user should also have the possibility to upload own recipes.

The other two participants didn't think that this application would support them because one participant wouldn't manage to keep the groceries in the fridge and pantry up to date since the registration is not automatically and one participant thinks it is too complicated in general.

Lightening Settings

The Philips Hue functionality was tested with a Power Point Mock up, simulating the user a fully operational prototype. Participants were asked to open the application and switch one bulb to red light, then to pink and then to increase the brightness. The participants found this application not that helpful and new. One participant said that those lamps are not supportive for him and are already available since 10 years. Another participant thinks it would be nice in a relaxation room after the sauna, but not in the flat.

Robot Notifications

Physical Activity Notifications: The notifications of Robin regarding physical activity were perceived as very nice and motivating by two participants, yet not interesting by two other

participants. One participant who was interested in this kind of presented information wished to have also a picture to see e.g. the boarder of Belgium in case Robin said that she already walked the distance of the Belgian border. Another participants said that simple messages like “Well done!”, as already presented in eWALL, are more motivating for him.

Sleep Notifications: The notifications and tips regarding sleep were interesting for most of the participants. One participant thinks it would be interesting to tell Robin the exact amount and kind of what he drank or ate to see if it really has an impact on his sleep efficiency. Additional information e.g. if he had a dispute at night, would be interesting as well. One participant said that she would rather adopt these tips when provided by a person she trusts as for example her physician. But in general, those provided tips of Robin are not new for her, thus, not that interesting.

Environmental Notifications: Robin’s Notification and tips regarding the temperature outside and inside the home were in general perceived as interesting, yet not very supportive for the participants because they can change the heating themselves (mentioned twice) or like to adapt the heating based on how they feel (mentioned once). One participant emphasized that the data must be correct in order to trust this information.

My Settings

The settings application was quite important to the participants who liked to decide who can see their data. One participant mentioned that she would give the data to her physician and caregiver in case they really have the interest and possibility to check them.

8.4 Conclusions

Lab test evaluation of new functionalities developed in the last part of the eWALL project from demonstration partners (RRD, IRCCS, AAU, and ATE) helped to collect punctual feedback and indications from users and experts at different levels and to get very broad views on what's valuable and what is to change in the final applications set. Those results will be used to make a step forward towards the completion of the platform and will be an opportunity to fix technical aspects and design weakness of new functionalities.

9 Appendix B – Small Scale Evaluation

The evaluation of the M25 prototype, which was the last part of the Small Scale Evaluations, started by the mid of November. Thus, the results could not be described in the D6.4. The evaluation partners agreed to involve those outcomes as appendix of D8.3.

9.1 SSE Cycle 3 Evaluation in Denmark

9.1.1 Second round of participatory heuristic evaluation

In a previous cycle of small scale evaluations we performed a participatory heuristic evaluation (PHE) at AAU. After the first round of PHE the eWALL user interface was changed radically. Consequently, we found it relevant to perform a second round of PHE on the new version of the eWALL user interface.

PHE is an expansion of traditional heuristic evaluation. Traditional heuristic evaluation is performed by a group of usability experts (UEs). The UEs perform an inspection of a user interface in which they identify usability problems. In PHE the UE inspection is supplemented with an inspection by work-domain professionals (WDP). The purpose of expanding the heuristic evaluation with WDPs is to supplement the theoretical knowledge of the UEs with the specific knowledge of the WDPs (Muller, Matheson, Page, & Gallup, 1998). We performed the PHE on the eWALL user interface in order to have both the UEs and the WDPs identify usability problems and thereby achieving a more nuanced picture of the usability errors present at that current time in the development process.

Materials and Methods

The PHE was performed at Aalborg University in a laboratory setting. Five UEs and two WDPs identified usability problems of the eWALL user interface. The PHE inspectors (n=7) were recruited from the Department of Health Science and Technology at Aalborg University, Denmark. The UEs (n=5) had an MSc.in Biomedical Engineering. The two WDPs who participated in the PHE had a background as trained nurses. The nurses also had a MSc. in Clinical Science and Technology.

Two researchers ran the inspection. The inspectors did their inspection one at a time. Before the inspection each inspector was introduced to the purpose and the potential user groups of eWALL. Moreover, each inspector was introduced to the list of heuristics and to a severity rating scale. The inspector was then asked to go through a number of tasks involving all functionalities of eWALL. The inspector was encouraged to think out loud while solving the tasks. All the usability problems that an inspector identified were noted, and the severity level was scored for each of the identified usability problems.

The inspectors identified each usability problem using the 15 heuristics defined by Muller et al. (Muller et al., 1998): 1) *System Status,* 2) *Task Sequencing,* 3) *Emergency Exits* 4) *Flexibility and Efficiency of Use,* 5) *Match Between Systems and the Real World,* 6) *Consistency and Standards,* 7) *Recognition rather than Recall,* 8) *Aesthetic and Minimalist Design,* 9) *Help and Documentation,* 10) *Help Users Recognize, Diagnose, and Recover from Errors,* 11) *Error Prevention,* 12) *Skills,* 13) *Pleasurable and Respectful Interaction with the User,* 14) *Quality Work,* 15) *Privacy.*

The severity of the identified usability problems was rated using a four level severity rating scale: 1) Cosmetic problem only, 2) minor usability problem, 3) major usability problem, and 4) usability catastrophe.

Results

In total, the inspectors identified 384 usability problems distributed between all of the 15 heuristics. Figure 23 shows how the use of the heuristics was distributed. The UEs used heuristic no. 7 the most (Recognition rather than recall), and the WDPs used heuristic no. 13 the most (Pleasurable and respectful interaction with the user). In total, heuristic no. 8 (Aesthetic and minimalist design) was used the most.

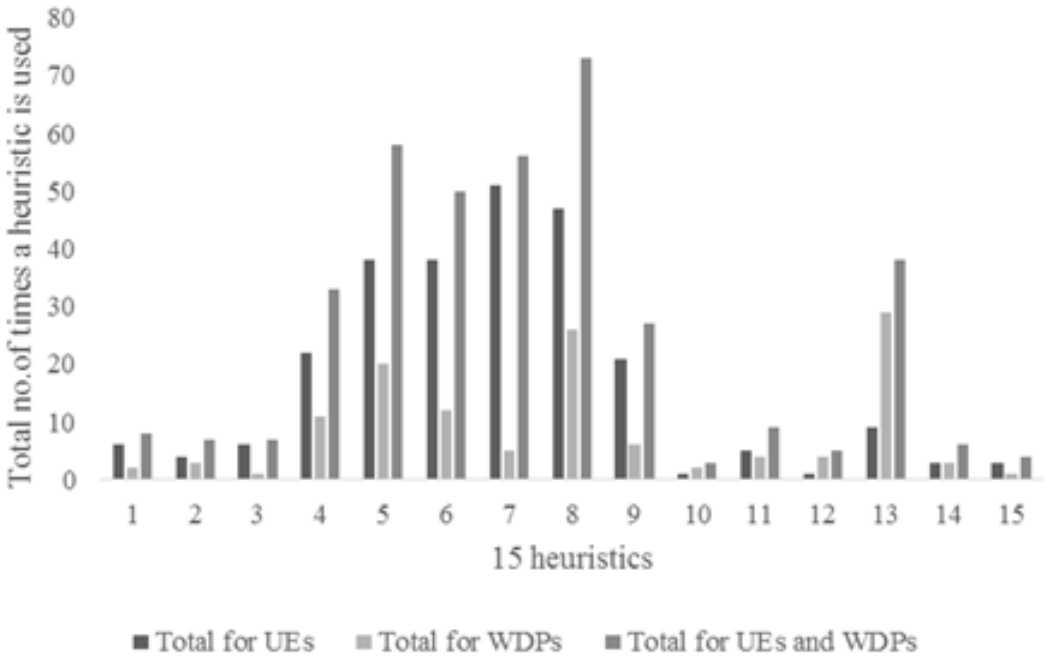


Figure 23: The distribution of heuristics used in the PHE. Number of heuristics used in total by the inspectors and separately for both the UEs and the WDPs.

The severity rating of the usability problems identified is illustrated in Figure 24. Severity grade number 2 was used the most by the UEs, and severity grade number 3 was used the most by the WDPs. Severity grade number 1 was used the least by both groups. In total, severity grade number 3 was used the most.

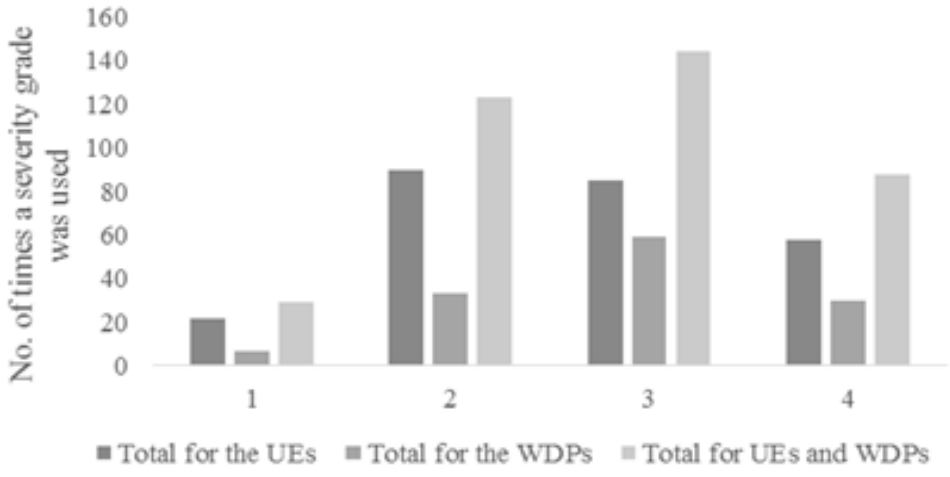


Figure 24:Distribution of severity grades. Number of times each severity grade was used by the UEs and by the WDPs

Conclusion

The second round of PHE on the eWALL interface identified 384 usability problems. The usability problems were most often rated with the severity grade number 3 (major usability problem). That demonstrated that eWALL needed further development to increase the level of usability. PHE showed to be a relevant tool in the interface development process as the UEs and WDPs supplemented each other in identifying different types of usability problems.

9.1.2 Cognitive walkthrough

Another usability test performed during the small scale evaluations cycle 3 was a cognitive walkthrough. A cognitive walkthrough is an evaluation technique that evaluates the design of a user interface (Rieman, Franzke, &Redmiles, 1995). The cognitive walkthrough was performed with an aim to evaluate the eWALL user interface by identifying usability problems.

Methods

The cognitive walkthrough of the eWALL user interface was performed by two usability experts. After the cognitive walkthrough, the usability problems that were identified in the cognitive walkthrough were presented to the other medical partners involved in the eWALL project. The medical partners were asked to rate the identified usability problems and add further usability problems if relevant.

Cognitive Walkthrough with experts

In Denmark both the usability experts who performed the cognitive walkthrough had a Master's degree in Clinical Science and Technology and extensive experience in the field of usability testing. Furthermore, both experts had knowledge of the eWALL system and its functionalities and had a background as healthcare professionals. In Italy, experts were 1 clinical neuropsychologist and 1 expert in tele-rehabilitation. In The Netherlands a group of elderly.

The experts were placed in front of the eWALL screen to have the best possible access to all the functionalities of eWALL (n=14). Prior to the cognitive walkthrough, the experts received an overview of the functionalities of the system. The experts kept in mind that the goal of the cognitive walkthrough was to evaluate each functionality by assessing whether or not one or several usability problems were present in each of the functionalities. The two experts evaluated 14 functionalities of the eWALL system including:

- My Activity
- My Sleep
- My Health
- My Everyday Life
- Games
- Environmental box
- TV
- Calendar
- Photo frame
- Main screen
- Weather forecast
- Active mode
- Passive mode

- Login

When a usability problem was identified, the experts followed the same procedure:

- The usability problem was described
- The location of the usability problem was described (in which functionality)
- The usability problem was rated using a four level scale (1-4): 1) *a cosmetic problem*; 2) *a minor problem;* 3) *a major problem*, and 4) *a catastrophe problem*
- A recommendation for improvement of the system was suggested
- The usability experts spend approximately six hours performing the cognitive walkthrough.

Including the other medical partners

The cognitive walkthrough resulted in a list of usability problems. The list of usability problems was uploaded to a joint internet folder that all partners of the eWALL consortium had access to. The other three medical partners then scored the severity of each identified usability problem. If any of the medical partners had identified usability problems that were not represented on the list, they were invited to add them to the list. Even though the medical partners were asked to use the same four-level scale as the experts from AAU had used, another level was added to the scale. The three remaining medical partners added the level 0 which indicated that the partner either did not acknowledge the problem or was indifferent to the problem.

Results

The experts identified usability problems in all of the 14 functionalities (Figure 25). In total, 119 usability problems were identified by the experts.Figure 25visualises the distribution of the problems across the different functionalities. The experts identified the most usability problems in the functionalities: 'TV' (n=21), 'Calendar' (n=20), and 'Environmental box' (n=18). The least usability problems were identified in the functionalities: 'My sleep' (n=1), 'Photo frame' (n=2), and 'My Everyday life' (n=3).

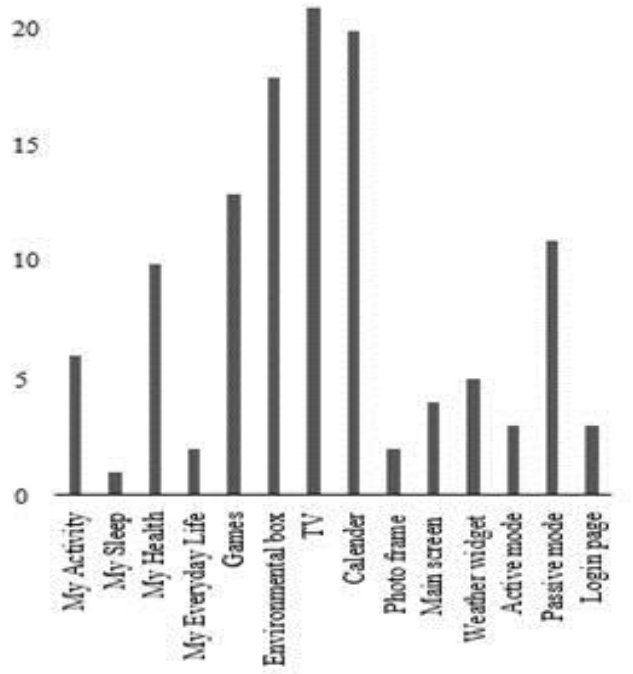


Figure 25: The distribution of usability problems among the 14 functionalities of the eWALL system identified in the cognitive walkthrough.

Figure 26 illustrates the distribution of the severity rates given by the four medical partners. As described, AAU did the first round of rating using a four level scale. The remaining partners used a five-level scale (0-4).

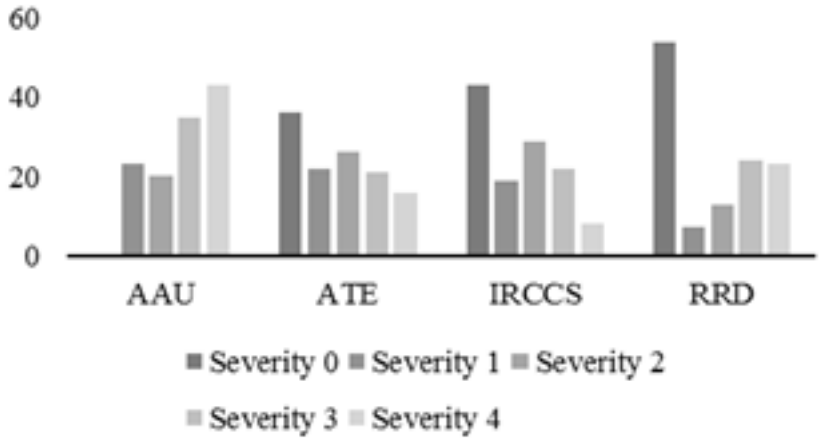


Figure 26: The distribution of the severity rates used by the four medial partners

AAU used severity rate 4 the most and severity rate 2 the least (please note that AAU did not include level 0 in their evaluation). ATE used severity rate 0 the most and severity rate 4 the least. IRCCS used severity rate 0 the most and severity rate 4 the least. RRD used severity rate 0 the most and severity rate 1 the least.

Conclusion

The cognitive walkthrough identified a great number of usability problems in the eWALL user interface (=119). The list of usability problems identified in the cognitive walkthrough served as a structured, concrete, and constructive collaborative tool.

9.2 SSE Cycle 3 Evaluation in Austria

For the third cycle of Small Scale Evaluations, ATE recruited participants both for a **focus group with people living with COPD** to evaluate the eWALL system as well as **interviews with caregivers and UX experts** to evaluate the associated eWALL Caregiver Web App Application.

9.2.1 Caregiver Web App Evaluation

In November 2015 four persons, two male and two female, from 32 to 73 years old (M= 56, 6) participated in the eWALL Caregiver Web App evaluation in Vienna. The evaluation focused on User Experience and acceptance of the users.

First, main aims of the eWALL project were explained to the participants, then they read and signed the informed consent form, a precondition for taking part in the evaluation. Thereafter, participants were asked to answer two questionnaires:

- Mobile Technology Questionnaire: assessing the use and knowledge of technologies such as smartphone, WLAN or Facebook
- User Experience Questionnaire: measuring the User Experience of a product by a semantic differential method (http://www.ueq-online.org/).

For the evaluation, the team used a task-based approach, meaning that participants were asked to fulfil different tasks without explaining them the structure of the application beforehand. The test leader asked the participants to think aloud during the tasks to allow the test leader to follow the participant's thoughts and issues to solve the task.
The following interfaces were tested: Login, Main screen, Notifications, Profile of patient, Physical activity, Vital data, Domotics, Daily activities, Thresholds, Memory Quiz settings (mock-up test with PPT slides), My Profile (caregiver profile).

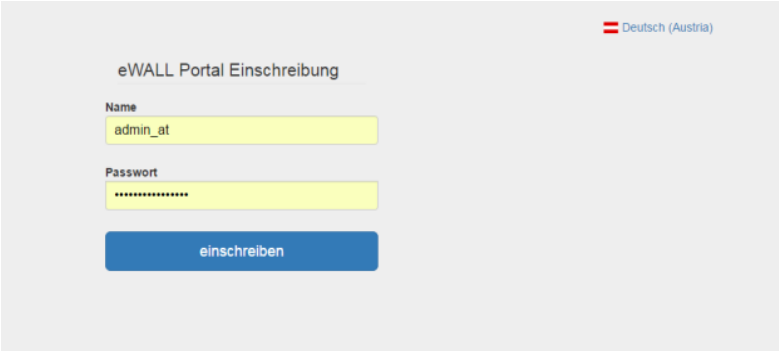


Figure 27: Login screen

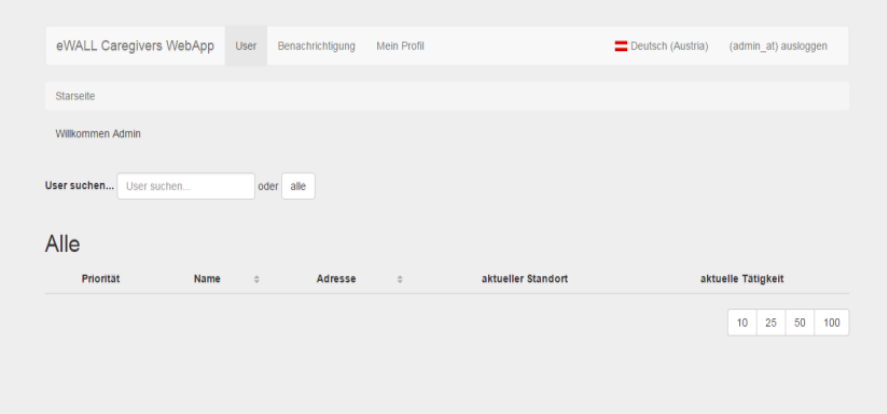


Figure 28: Main screen

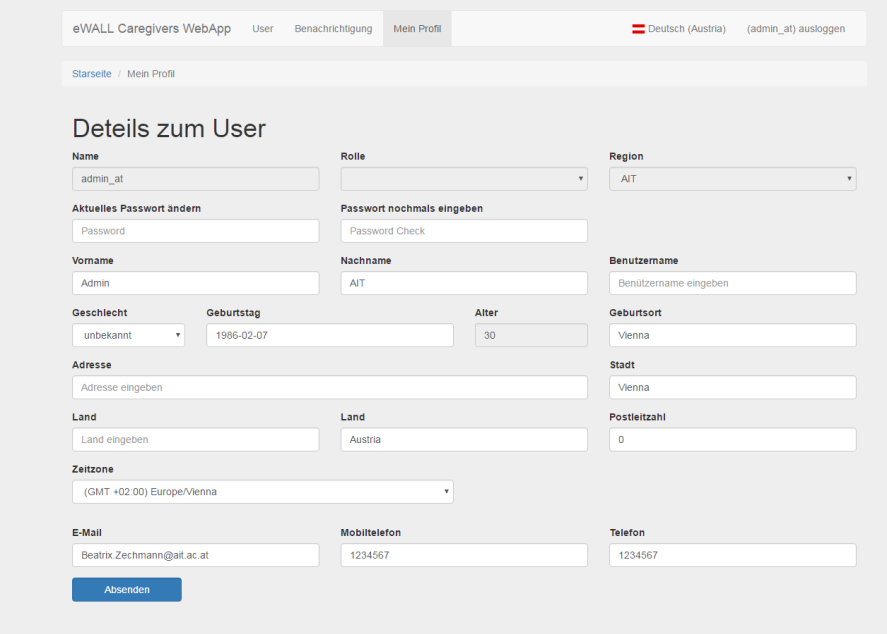


Figure 29: My Profile (caregiver profile)

Description of Participants

Two of four participants were already retired. Three participants were caregivers, one participant was UX expert and one participant was both carer and UX expert. The highest level of successfully completed education was university for three participants and high school for one participant. Three participants were using smartphones and one participant a mobile phone on a daily basis. Also, three participants were using mobile internet and a PC/laptop at least once a day, whereas one participant used both at least once a week.

Results

Based on the Usability Test we could elaborate specific and realizable recommendations derived from the participants' responses. In general, the login/logout and the usage of all functionalities were clear to participants. Some German words were suggested to be changed. The most recommendations for change were focusing on the design: other colours, bigger font etc. The following table shows all the observations and recommendations of the Caregiver Web App Evaluation.

UI	Observation and Recommendation
Login	change in German "einschreiben" to "Anmelden"
	change in German "erinnere mich" to "angemeldet bleiben"
Main screen	add a frame around the text to give a better orientation for the user
	make the font bigger (minimum should be the text "eWALL Caregiver Web App" in the upper left corner)
	change in German "ausloggen" to "abmelden"
	change in German "User" to "Betreute Person"
	persons are missing in the list in case you go back from the notifications - change this

	yellow stars are too bright - change the colour nuance to a bit less intensive yellow
	enlarge icons for current location
	for those people who decided to hide their current location, write "hidden" ("nichtfreigegeben" in German)
	add text description beneath the icons since icons alone are not always understandable (on the smartphone icons alone are ok since there is less space)
	change the grey background colour to light blue
	search box and buttons look very similar - make the buttons look more like buttons
	more people appear when clicking "all" - show them all at first
	display the eWALL logo instead of writing eWALL in the upper left corner, write "caregiver Web App" below the logo
Notifications	make folders for the different type of notifications
	change colour of red bar to a less intensive colour
	change the word "priority" here, since it has another context compared to priority of the users
	when ordering the people after their name and then also after the date, it is not ordered by name anymore (in case I'm just interested in Bob, it should show his notifications order in a row ordered by the date) - make this possible
	change in German "Benachrichtigungen" to "Benachrichtigung"
	change in German "öffnen" to "anzeigen"
	show the icons when opening the details of notifications
	use more colours to separate the text visually
	delete the information "out of range", write only e.g. "Kitchen CO = 80; normal value: XX", show the icon
	make the arrows for ordering more prominent/bigger and let them look like buttons
	give the possibility to see also older information (during the tests users could just see info till the 16.Dez)
Profile of patient	after actualizing the profile, the app crashes down
	show first the systolic and then the diastolic blood pressure
	the icons for domotics are not clear, delete the exclamation mark and show exactly the problem similar to the bars for physical activity
Physical activity	make the legend more detailed
	give the information that those are daily values: "Daily overview" ("Tagesübersicht" in German)
	delete the "search" button and update the overview directly after changing the date

	when scrolling down to the calories overview, leave the upper bar for changing the date etc.
	write down the average value of the selected time span - right beneath the graph
	change the language of the mouse hovers to German/Dutch/...
vital data	when unchecking and again checking the diastolic blood pressure, the colour of diastolic blood pressure is wrong
domotics	instead of showing the lux, the time span that the light was turned on would be more interesting
	delete the information about lux
	symbol of gas is not clear - find a better one or write the gas below
daily overview	add an overview of the daily activities
	add information about time unit
	show activities lasting more than 120 min in hours
	colours are wrong after unchecking and again checking the activity
	add the current time of the day
	leave the filter setting after updating
	add a loupe function to see details of the slim bars
Thresholds	wish to have also information about the body temperature
	delete the box with information about the user
	use settings as the link instead of clicking on "thresholds" - similar to the other boxes (physical activity etc.)
	change the name "thresholds" since also priority etc. can be adjusted here
	make the font of "Standardeinstellungenändern" bigger (at least in German it is very small)
	explain what the different gasses are and what problems could occur
	when scrolling down to the calories overview, leave the upper bar for changing the date etc.
Memory Quiz Settings	when uploading a picture, the name I choose for it is not shown afterwards - show the name or delete the option to add a name
My Profile	change in German "Absenden" to "Speichern"
	why is a nickname needed? - delete that
	change in German "State" to "Bundesland"
	who needs all those information - delete most of it
	change in German "Deteils" to "Details"

in general	too many notifications - give the option to decide which information to see
	give the possibility to add contact details for responsible persons (doctor, nurse, ..)
	change the background colour to light blue
	how does system recognise house work? needs more information than movement sensor

One caregiver thinks he wouldn't be interested in the Daily Activity Overview since the person he cares for is not living alone, thus, this information is not important to him. Another caregiver explains she is currently manually writing down all the health values of the person she cares for. She thinks that such technical systems reduce the personal contact to the person. Furthermore, she doesn't want to control how thoroughly housework was done. Another participant highlighted to take care of privacy aspects within eWALL. Participants wish to decide which information in general they can see and also emphasize the need to personalize the notifications that are interesting for them. Currently, too many notifications are shown which affects the clarity of the interface. One idea was to get push notifications on the smartphone.
The participants appreciate the application in general, especially for carers of people living alone. However, they point out that it still has some minor flaws to be adapted. One participant mentioned the importance to set different languages in the application since formal caregivers could have another native language.

UEQ Outcomes

This part explores the user experience of the participants using the UEQ questionnaire. The above average attractiveness score and the good perspicuity score mean the eWALL Caregiver App is on average beautiful and easy to use and intuitively to learn. The effectiveness parameter counts for each participant's perception of their own task accomplishment. This parameter is the only one perceived as bad. **The dependability score is excellent, due to the fact that usage is easy. The eWALL Caregiver App is perceived as average stimulating, yet the novelty score is good**.

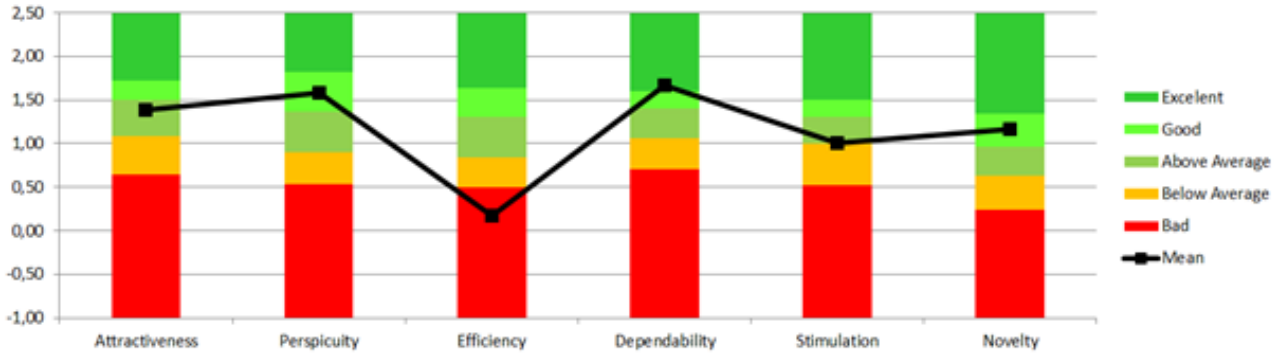


Figure 30: UEQ Outcomes Caregiver Web App Evaluation in Austria

Conclusion

As a conclusion, the test outcomes prove that the eWALL Caregiver App is a promising technology and caregivers would adopt it if the information presented is better structured and the design is adapted. Furthermore, personalisation is necessary to adapt the shown information to the individual user of the Caregiver Web Application.

9.2.2 eWALL System evaluation

Participants

Of the four participants recruited for the focus group, two persons cancelled on the day of the evaluation due to health reasons. The remaining two participants were both male and 66 respective 74 years old. Both were retired and had a High school Certificate. Only one participant used a smartphone but less often. They were using a PC or laptop daily respective weekly but did not use tablet PCs at all. The participants were diagnosed with COPD 6 (GOLD III-IV) respective 14 (GOLD II-III) years ago. When scoring their subjective experiences impairments in everyday life due to health problems on a 10 point scale, where 10 means that the health condition completely hinders them in everyday life, one participant answered with 8 (needs support with gymnastics and house cleaning), the other one with 3 (doesn't need support in everyday life).

Table20: Overview participants of eWALL System evaluation in Austria

Participant Nr.	Age	Gender	Diagnosed	GOLD level	Impairment (1-10)	Support needed
1	66	male	2009	III-IV	8	Gymnastics, House cleaning
2	74	male	2001	II-III	3	--

Results

Task 1: Main Screen

At first sight the participants didn't know what to do with all the objects on the screen. The window with weather information war clear and they even understood the steps beneath the lava lamp. Nevertheless, one participant was not sure if the steps shown cover only the ones during the eWALL training or the steps of the whole day. One participant explicitly said that data protection is highly important for him and a data leak would be a problem since he doesn't want to get commercial advertisements later on. The participants had problems with identifying the aim of the books when looking at them in the main screen. One participant asked if he can establish a phone call with his family when touching the family picture. When looking at the well-being ads, which was currently showing the breakfast reminder, the two participants had different opinions about their usefulness. One participant thinks he won't need those reminders since he knows himself what to do and when to eat breakfast ("I'm not completely stupid!"). The other participant explained that he is sometimes staying in bed longer and therefore would be happy to get this reminder. They agreed that those notifications are more useful for people living alone in their flat compared to those living together with another person. The calendar overview in the screen was perceived as useful for medication reminders.

Task 2: My Activity

The different activity types and colour schemes shown in the My Activity application were easily understandable. One participant expected a different judging for the activity running as it is much more tiring than others. The steps overview was most interesting for participants.

Task 3: My Sleep

One participant felt too much controlled and observed when looking at the sleep data and didn't need that much information about his sleep. They wished to have also the nap after lunch included

in the overviews. Additionally, one participant wished eWALL would detect sleep apnoea. In general, the participants perceived this functionality less important for them. One participant explained that all those curves and values cannot reflect his subjective experienced sleep quality, e.g. if he had a nightmare or a bad sleep. One participant would share those data with his family or medical personnel, the other participant would only share it in case he cannot live independently anymore.

Task 4: My Health

In general the participants understood all the information shown and interpreted the data correctly. Also the process of measuring the oxygen saturation and pulse was easy for them. One participant additionally wished to have weight measurement included, as he easily loses weight. One participant would share this data with the family, the other one would only share it with the physician as this is not important for his family members.

Task 5: Daily Functioning Monitoring

The daily overview of activities was not perceived as important by the participants. One participant explained that he notes important things down. The other user used the term "smartphone-effect" in this context, whereby he meant that eWALL implies far too many functionalities but only very few of them are really usable for him.

Task 6: Cognitive Training/ Games

In general, the games were enthusiastically played by the participants. Nevertheless, one participant showed up the controversy that on the one side the users of eWALL are supported in their cognition on the other side they are encouraged to train their brain – this doesn't fit together. As the game overview shows a chess game, one participant expected a chess game.

Task 7: Playing Games

One participant prefers to play with real cards etc. as he enjoys the haptic experience. But he adds, that this is maybe depending on the generation and will probably change in future. Additionally, he wishes to play against other users. They agree that those games are predominantly for people living with cognitive impairments, rather than for COPD.

Task 8: Physical Training

The participants would open the activity book for physical training instead of the video trainer. When opening the application, they understand the aim of it and how to proceed. One participant suggested the screen should mirror the user, similar to the fitness studio. He also thinks that people who need those easy exercises may not be able to use the system anymore. They both emphasize that the program has to be perfectly personalized to allow the optimal exercises for the individual, otherwise they won't use it. One participant has a DVD with exercises at home, but he just looks at it once and then does the exercises without the DVD as he doesn't want to look at the screen all the time. The question after the exercises "How much did you appreciate the exercise?" was seen sceptical by both participants, as an exercise is a challenge but not something to appreciate.

Task 9: Domotics

The first impression of the domotics application was that it can be used for regulating the heating in the apartment. One participant explains that he doesn't use temperature sensors because he regulates the temperature according to his felt perception. He is not sure if he would then look at those values if using eWALL at home. Both participants didn't see any benefit of having information regarding illumination intensity. Both use humidifier in their home, either simple pots or a more advanced one

that vaporizes salt water between 0 and 4 a.m. in the night. Nevertheless, they do not yet use humidity sensors but think that this would be very beneficial for them.

Task 10: Calendar

Currently, both participants are still using paper calendars. One participant explained that his fingers are too big for touch screen interaction on his smartphone. Although he is confident with using computers, he doesn't use the functionalities of the smartphone due to this.

Task 11: General experience

In general, the participants perceived the usage easy, but would prefer to have less functionalities as they don't need all of them. They most appreciated the My health, My Activity, Video Trainer and Weather application. Additional functionalities will be more interesting when they already need a caregiver, they think. In this case the caregivers will decide which functionalities are useful. Less interesting features for the participants were the picture album, My Sleep and the cognitive games. The participants repetitively emphasized the importance of data security within eWALL. Nevertheless, they would share relevant data with their physician and would advocate the eWALL Caregiver Web Application.

Asking them for additional functionalities, they wished more COPD related exercises, e.g. for reducing dyspnoea or removing mucus. Further information and advice regarding COPD would be appreciated as well, both for the users but also for caregivers.

9.3 Conclusion

In Conclusion, the evaluations shows that a good personalization is a key acceptance factor for the usage of the eWALL system. The participants clearly emphasized that it currently involves too many functionalities, with some of them being not important to them in the current situation. Nevertheless, they think that other functionalities would be more important when they need a caregiver. Personalization should both be implemented on a broader level to select the currently supportive functions and applications, but also on a more detailed level to select e.g. those exercises or games that challenge but do not overwhelm participants.